Testimony on H.R. 1053:
The Common Cents Stock Pricing Act of 1997

Lawrence Harris
Marshall School of Business
University of Southern California

Presented to
U.S. House of Representatives
Committee on Commerce
Subcommittee on Finance and Hazardous Materials
April 16, 1997

Lawrence E. Harris
Professor of Finance and Business Economics
Marshall School of Business
University of Southern California
Los Angeles, CA 90089-1421

Voice: (213) 740-6496
FAX: (213) 740-6650
E-Mail: LHarris@USC.edu

Summary

Decimalization is a significant issue only to the extent that it affects the size of the minimum price increment, or tick. If the tick is too large, spreads will be too large. Traders will not be able to effectively compete on price. If the tick is too small, front-runners will exploit investors who offer to trade.

Investors protect themselves against front-running by hiding their orders. They will display less size, they will employ more floor brokers, they will break up their orders, and they will shift their trading strategies towards market orders from limit orders. All these responses increase their transaction costs and make markets less liquid and less transparent. Empirical research shows that markets are less transparent when the tick size is small.

All oral auctions have significant price increments to protect traders from others who would unfairly obtain precedence by improving price by a trivial amount.

These issues apply only to oral auction markets like the NYSE and AMEX that use order precedence rules to arrange trades. Tick sizes in dealer markets like Nasdaq do little more than set a minimum bound on bid/ask spreads. Tick sizes should therefore be smaller in Nasdaq.

The bill does not mandate that any market adopt a one penny tick, but in practice all must if any one does. Congress must therefore consider carefully the issues raised by this bill because the exchanges and the SEC will not be able to correct any mistakes made here.

Estimates of the benefits to the public from decimalization are grossly overstated. They overcount the volume that would benefit from smaller quoted spreads. They do not adjust for the expected decline in the size of price improvements. They ignore the increase in commissions that will ultimately result from a decrease in payments for order flow. They do not estimate the increased costs that large traders will have to pay to avoid front-runners.

Testimony on H.R. 1053:
The Common Cents Stock Pricing Act of 1997

Lawrence Harris

Thank you for this opportunity to testify about decimalization.

I have been studying the effects of trading rules on the securities markets for 15 years. During the last 10 years, I have been especially interested in how the minimum pricing increment – the 1/8 tick – affects trading.

My interest in decimalization primarily concerns how it will affect the size of the tick. Whether traders use fractions or decimals is not a significant issue compared to the size of the tick that they do use.

When I first thought about ticks, I did not understand why markets should have them at all. It seemed obvious that a large tick impeded competition among traders. I did not understand why a trader who wanted to improve prices by less than 1/8 should not be allowed to do so. My training as an economist suggested that we would be better off if traders were freely able to compete on price.

I was especially concerned about how the tick affects dealer spreads. Since the spread can be no smaller than one tick, it seemed to me that a large tick supports artificially high prices for dealers.

Today, I remain concerned about the size of the tick. For some stocks, the tick is probably too large.

I have come to understand, however, that my original thinking about tick size was flawed in some important respects. After 15 years of studying how various markets operate, I now recognize why oral auction markets like the NYSE and AMEX must have an economically significant tick to best serve public investors.

Interestingly, the reason is one that this subcommittee which also studies problems with hazardous materials will readily understand. For the first time, I may understand the wisdom of combining finance with hazardous materials.

The common element has to do with the fact that unregulated markets are only in the public's interest if people do not do things that hurt or benefit the public for which they are not appropriately penalized or rewarded. We regulate hazardous materials because people will often take risks that affect the rest of us when they do not have to pay for the resulting adverse consequences. We likewise subsidize road construction in the various states because many benefits of building roads do not accrue to the states through which they pass. If we did not subsidize roads, states would build fewer of them and we would all be worse off.

In the securities markets, public investors who stand willing and ready to trade with other investors provide a benefit to the public for which they are not always compensated. The benefit that these investors provide is liquidity. Investors who show that they are willing to trade give everybody options to trade. A regulatory problem arises because investors must give these options away for free. These trading options benefit the public, but the investors who create them are not always compensated. Worse, these investors are often exploited by other traders. As a result, fewer investors are willing to show that they are willing to trade than would be best for the public.

It is easiest to understand the problem by considering a simple example. Suppose that you submit a limit order to buy stock for 20 dollars. This order gives everyone in the world an option to sell stock at 20 dollars. A clever trader who sees your order can exploit it by submitting his own buy order at 20.01. If a market sell order then arrives, he will trade instead of you. If price then rises, he profits instead of you. If it appears that price will fall, however, he will sell to you at 20. You lose either way. The cost to the clever trader of exploiting your order is the potential one penny loss assumed in this example.

Exchange markets protect investors from this front-running strategy through their minimum price increment rules. An economically significant tick raises the potential costs of the front-running strategy. Any trader who wants to go before another trader must offer a non-trivial improvement in price. This is not only good economics, it is also fair.

You can convince yourself that this front-running strategy is a form of parasitic trading by considering what would have happened if you had canceled your order. The front-runner would have immediately canceled his order.

If we made the tick too small, public investors will protect themselves against this front-running strategy by hiding their orders. They will display less size, they will employ more floor brokers, they will break up their orders, and they will shift their trading strategies towards market orders from limit orders. All these responses will increase their transaction costs and make markets less liquid and less transparent.

In our example, the market order seller received a higher price because the quick trader stepped in front of your order. But if you had not shown your order, the seller might not have received even 20. If we allow front-runners to drive you out of the market, both sides will be hurt.

These arguments are not just speculative theories. Empirical research done by me and others clearly shows that markets are less transparent when the tick size is small.

The issues that I have discussed apply only to oral auction markets like the NYSE and AMEX. Dealer networks like Nasdaq do not have precedence rules to regulate who trades first. Tick sizes in these markets do little more than set a minimum bound on bid/ask spreads. Tick sizes should therefore be smaller in these markets. A decrease in tick size, however, will have less effect in dealer markets than in exchange markets because order preferencing arrangements give dealers little incentive to improve prices.

The bill before us does not mandate that any market adopt a one penny tick. In practice, however, if any traders are allowed to quote on pennies, all markets will have to permit their traders to match these prices. This is because brokers must obtain best execution for their orders. It is therefore very important that Congress consider carefully the issues raised by this bill. A mistake made here cannot be corrected by the exchanges or the SEC.

In retrospect, my early view that exchange markets should not have significant price increments foolishly ignored the fact that all oral auction markets have them. I should have asked myself why art, land, tobacco, car and even charity auctions all have significant price increments. The answer is the same for all. Oral auction markets have significant price increments to protect traders from others who would unfairly obtain precedence by improving price by a trivial amount.

My training as an economist has allowed me to recognize the tremendous benefits that competition brings to our economy. I solidly favor competition, but the playing field must be fair. An economically significant tick has helped us create the most competitive and liquid equity markets in the world. It should be smaller in some cases, but not all. Let us be very careful with this seemly trivial issue.

Supplemental Materials:

“Some Questions and Answers About Decimalization,” attached.

“Decimalization: A Review of the Arguments and Evidence,” USC Working Paper, March 1997.

“The Economics of Best Execution,” USC Working Paper, March 1996.

Some Questions and Answers About Decimalization

1. Who benefits and who loses from smaller tick sizes?

Dealers at exchanges, computerized traders, and small public market order investors will benefit. Limit order traders, large traders (the vast majority of whom manage money for small public investors) and Nasdaq dealers will lose.

Exchange dealers benefit because a smaller tick allows them to trade in front of their limit order book. Presently, when the limit book has buy orders at 20 and sell orders at 20 1/8, specialists can hardly trade at all. They cannot buy ahead of the limit book at 20 and they cannot buy from their booked sell orders at 20 1/8. The only way that they can buy is by waiting until an incoming market sell order arrives and filling it at 20 1/8 (if no public traders in the crowd want to trade at that price). Likewise, the specialist can only sell at 20 if some market buy order arrives that the public does not want. Buying high and selling low is not the normal path to riches. Decimalization will help specialists by allowing them to step in front of their books to intercept incoming market orders at more favorable prices.

Computerized traders benefit because they are most able to exploit the front-running strategies that become more profitable when the tick size is smaller. Front-running strategies work best when the front-runner can submit and cancel orders faster than can their victims. Computerized traders are very fast traders.

Small market order traders will benefit because spreads will decline.

Limit order traders will be hurt because spreads will decline and because of the increased front-running.

Large traders will be hurt because of the increased front-running.

Nasdaq dealers will be hurt if the Nasdaq composite spread narrows. The recently adopted order exposure rules will tend to decrease these spreads.

2. The markets greatly benefited from the reduction in commissions in 1975. Why should we not expect the same benefits from a reduction in tick size?

Commissions tax all public trades. Wide spreads tax only market order traders. If spreads decrease as a result of decimalization, only small market order traders will be better off, and then mostly only in stocks that now trade at one tick spreads. Limit order traders will be worse off.

3. How will decimalization affect payment for order flow and order preferencing arrangements?

If spreads narrow, dealers will pay less for orders. This will weaken order preferencing arrangements. Dealers in exchange-listed stocks will be most impacted because these are the stocks for which spreads will narrow the most. Small market order customers will get better prices. They will ultimately have to pay higher commissions because brokers will not receive as much payment for their orders.

4. How will decimalization affect regional exchanges?

Dealers at regional exchanges obtain most of their order flow through internalization and order preferencing arrangements. If spreads narrow, these dealers will be hurt. Although they will be better able to step in front of their customers' limit orders, they will not benefit much from this because they do not receive many limit orders. Regional exchanges will be hurt by decimalization.

The regionals will do better under decimalization only if the NYSE and AMEX choose not to narrow their ticks. This seems unlikely.

5. **What effect will decimalization have on price improvement rates for market orders?**

Dealers will improve prices for market orders more often, but the improvements will be smaller. The empirical evidence from the Toronto Stock Exchange supports this view.

6. **What do you think about the estimates of the benefits of decimalization that others have presented before this committee?**

These estimates greatly overestimate the benefits of decimalization. They overcount the volume that would benefit from smaller quoted spreads. They do not adjust for the expected decline in the size of price improvements. They ignore the increase in commissions that will ultimately result from a decrease in payments for order flow. They also do not estimate the increased costs that large traders will have to pay to avoid front-runners.

Omitting these factors produces estimates that are unrealistically large in comparison to current dealer profits.

7. **How much do you estimate the public will save from decimalization for each cent of spread reduction?**

Since it is very difficult to quantify the costs that front-running imposes on large traders, I will ignore these costs. I will note, however, that large traders are extremely sensitive to the exposure of their orders. For example, it would be fair to say the most of the floor community at the NYSE exists because large traders are unwilling to widely expose their orders. Since the cost of maintaining 2000 floor brokers and their clerks is probably at least 300 million dollars per year, it seems clear that the front-running problem is serious.

To estimate the potential savings to public investors that would result from smaller spreads, we must first estimate the total volume of investor trades that would benefit from smaller spreads. This requires that total trading volume be decomposed into three components: trades between investors and dealers, trades between public investors, and trades between dealers. Narrower spreads benefit the public only when they trade with dealers at their quoted prices. When a public investor trades with another investor, whatever one investor gains from a narrower spread will be exactly offset by the other investor's loss. This is also true for dealer-to-dealer trades.

In 1996, approximately 125 billion shares were traded in exchange-listed firms and an additional 125 billion shares were traded in Nasdaq firms. In exchange-listed shares, dealers participated in about 20 percent of the volume. The remaining volume came from trades where investors traded directly with other traders. This suggests that only 25 billion exchange-listed shares would have benefited from a smaller spread. In Nasdaq stocks, dealer-to-dealer trading probably accounts for about 20 percent of total volume. Public-to-public trading arranged through block brokers and through Instinet probably accounts about 20 percent, perhaps more. The remaining 60 percent (or less) of trading volume consists of trades between public traders and dealers. Of this, about half involves large public institutions who presently negotiate trade prices down to 1/64's. Their trade prices are very often inside the quoted spreads. It seems unlikely that they would benefit much from smaller spreads. This leaves about 30 percent of Nasdaq volume which would benefit from smaller spreads, or 38 billion shares. Summing up the estimates for exchange-listed and Nasdaq stocks gives 63 billion shares.

A one cent decrease in the spread benefits a buyer or a seller only by ½ cent because the spread is the difference between the quoted buy and sell prices. If we multiply the crude 63 billion share impacted volume estimate by ½ cent, the resulting estimated savings are about

300 million dollars per penny of reduced spreads: 125 million for listed stocks and 175 million for Nasdaq stocks.

These estimates are quite imprecise since I am not intimately familiar with the allocation of volume to trade type. These estimates also do not account for changes in price improvement rates. The exchanges and Nasdaq should be able to provide much more precise information about these issues.

I do not believe that my estimate of 300 million dollars of public savings per penny of reduced spreads is credible. To realize these savings, dealer profits would have to decline by 300 million dollars per year per penny of reduced spreads. Although I do not know about dealer profitability in Nasdaq, I do know that NYSE specialist firms profits last year were about 200 million dollars. Much (most?) of these profits probably came from commissions as opposed to trading profits. If the dealing profits totaled 100 million dollars, they would be smaller than the 125 million dollars projected savings in listed-stocks. If the estimate is credible, decimalization will cause the dealers to quit dealing. More likely, the estimate is not credible.

Note again that decimalization is less likely to narrow spreads on Nasdaq than on the NYSE. The NYSE time-precedence rule rewards traders who improve the price. Since Nasdaq does not have a time-precedence rule, traders there have much less incentive to post narrower spreads. Decimalization in Nasdaq stocks will most likely narrow spreads only in stocks that currently have quoted spreads of 1/8.

In general, decimalization will have more impact on the 1/8 spread stocks than on the other stocks. We should keep this point in mind when evaluating the one-penny average spread reduction estimates. Although these estimates are computed over all stocks, not all stocks will benefit.

8. How large do you think the tick should be?

Exchanges should set the tick so that the quoted spread is two ticks about half the time, and one tick the remainder. This will ensure that there are adequate opportunities for price improvement while protecting investors from front-running.

Decimalization:
A Review of the Arguments and Evidence

Lawrence Harris
University of Southern California

Lawrence Harris
Professor of Finance
Marshall School of Business
University of Southern California
Los Angeles, CA 90089-1421

Voice: (213) 740-6496
FAX: (213) 740-6650
E-Mail: LHarris@USC.edu
Web: http://LHarris.USC.edu/

Version 1.1

April 3, 1997

The latest draft of this manuscript can be downloaded in Adobe Acrobat PDF format at http://LHarris.USC.edu/Acrobat/Decimal.PDF.

I would greatly appreciate all suggestions and comments.

I am grateful to the New York Stock Exchange, Inc. for financial support for this project.

Executive Summary

The minimum price increment (tick) determines what prices traders use. The tick is a decimal fraction in some markets and a fraction based on powers of two in other markets. The US Congress is presently considering a bill that would require the US stock markets to convert to decimal pricing. The likely outcome of decimalization would be a smaller price increment.

Proponents argue that decimal prices are easier to use than fractional prices and that decimalization is necessary to modernize US markets. More substantially, they argue that a smaller price increment would encourage price competition, narrow bid-ask spreads and decrease payment for order flow. Narrower spreads would ensure better prices for retail market orders, but less payment for order flow would raise retail brokerage commissions. Proponents also argue that decimalization is necessary for US markets to compete effectively against other markets.

Opponents argue that a smaller price increment would shift power from public traders to professional traders by making it easier for professionals to step in front of public limit orders. As a result, public traders will display their orders less and switch from limit order strategies to market order strategies. Quotation sizes will decline, transaction costs will rise and the markets will become less transparent.

The Canadian stock exchanges switched to decimal prices in April 1996. In the process, they decreased the tick from 12.5 cents to 5 cents for stocks priced above 5 dollars. Quoted spreads narrowed by about 4 cents but quotation sizes also declined substantially. Volumes did not change nor did the US market share of trading in cross-listed Canadian stocks. Several other international exchanges recently decreased their ticks with similar results.

The effect of tick size on market quality has also been studied by examining how stocks trade on different tick sizes. Small tick stocks have narrower spreads and less quotation size displayed than do large tick stocks. In markets that allow traders to submit limit orders that are not fully displayed, traders choose to display less size when the tick is small.

Some analysts have estimated the potential annual cost savings to the public of decimalization by multiplying half the projected decrease in spreads by annual trading volume. This method produces estimates of about 2 billion dollars per year for NYSE stocks. This is about 10 times larger than 1996 NYSE specialist profits, and about 2.5 times larger than their total revenues. This method grossly overestimates the potential cost savings because it implicitly assumes that the public trades only with dealers. Most trading, however, is between public traders. A cost savings to one public trader will represent an increased cost to another public trader.

All empirical results concerning tick size come from studies of exchanges in which a time-precedence rule encourages traders to improve price. Tick size is important in these markets because it determines the cost of obtaining precedence through price. The effect of tick size on trading in dealer networks is probably much smaller than in exchange markets because dealer markets do not enforce time precedence among dealer quotes. Decimalization is therefore unlikely to have much effect on payment for order flow or order preferencing in dealer markets.

The empirical results suggest that small market order traders and professional traders benefit from a smaller tick. A decrease in tick size hurts large traders and all public traders who use limit orders to compete with dealers.

1. Background

All markets have a minimum price increment (tick) that determines what prices traders use. In some markets, the increment is a decimal fraction, for example, 0.01, 0.05, or 0.1. In other markets, it is a fraction based on powers of two such as 1/2, 1/4, 1/8, or 1/16. In markets organized by exchanges or dealers, the organizer usually sets the tick. In other markets, traders set it themselves by common practice.

The tick varies substantially by market and location. Stock, bond and options markets in the US and Canada have traditionally used prices denominated in eighths. European and Asian markets typically use decimal prices. The practice in futures markets varies. Grains and some interest rate contracts use fractional pricing. Industrial commodities, stock indices, foreign exchange and some interest rate contracts use decimals.

Some decimal-denominated markets are de facto fractional markets. For example, the tick used to trade gas oil futures at the International Petroleum Exchange is 0.25 dollars. The tick used in most Italian stocks is 25 lira.

The size of the tick, expressed as a fraction of price, varies substantially across markets and also within markets. The variation does not depend on whether the market uses fractions or decimals. For example, a US government bond priced at 100 trades on 1/32 increments, which is 0.03 percent of price. In contrast, a Japanese stock priced at 1200 yen trades on 10 yen increments (0.83 percent). A Japanese stock priced at 800 yen, however, trades on 1 yen increments (0.13 percent). A typical 50 dollar stock at the New York Stock Exchange trades on a 1/8 increment (0.25 percent) as does a 10 dollar stock (1.25 percent).

Various markets are now experimenting with their minimum price increments. The American Stock Exchange decreased their tick from 1/8 to 1/16 dollar for stocks priced under 5 dollars in August 1992 and under 10 dollars in February 1995. In March 1997, its board voted to apply this change to all of its stocks. Canadian stocks switched to decimal pricing in April 1996. The Nasdaq board voted in March 1997 to permit quotations on sixteenths. US Representatives Oxley and Markey recently introduced a bill that would require decimal pricing in the US stock markets.

The next section of this paper briefly introduces the arguments for and against decimalization. Section 3 then surveys the evidence currently available. The paper concludes in

Section 4 with a brief discussion of the limitations of current research and with some suggestions for future research.

2. Issues

The arguments for and against decimalization fall into three categories.[1] Issues involving ease of use and market image are generally thought to be superficial. Issues involving competitiveness appear most substantial.

This section surveys each of these arguments as they are most commonly presented. Where appropriate, commentary on the economics underlying these arguments is also presented.

2.1 Ease of use

Argument in favor: Decimal prices are easier to use than fractional prices because arithmetic calculations are simpler with decimals than with fractions. For example, most traders find it easier to easily subtract 0.31 from 0.75 than 5/16 from 3/4.

Argument against: Fractional prices assist traders in their negotiations by making it easier to split the difference between a bid and an offer.

Since computers programmed to recognize fractions do most calculations, the issue is not significant. For example, investment tracking programs like Quicken and spreadsheet programs like Excel handle fractions seamlessly.

A change to decimals would incur substantial software costs for exchanges, dealers, and brokerages that use old systems.

If US markets thought that they could save costs by switching to decimals, they would do so without regulator intervention.

Commentary: The cost of changing to decimals is decreasing since most new security industry software systems support both systems.

[1] Peake (1993), Ricker (1996, 1997) and Wallman (1996) present the case for decimalization and provide some discussions of the case against decimalization. Before this survey, no study collects the arguments against decimalization into one place. Several studies discuss various elements of the case, although the discussion is often tangential to their primary purpose. These studies include Harris (1991a, 1993, 1994, 1996), Amihud and Mendelson (1991), Cordella and Foucault (1996), Seppi (1996), Battalio and Holden (1996).

2.2 Market Image

Argument in favor: Decimal prices present a more modern image of our markets than do fractional prices, the origin of which is often attributed to 16th century Spanish pieces of eight.

Argument against: The use of fractions may have more to do with a desire to split the difference than with Spanish pieces of eight.

How important could this issue be, given that the US is widely known to have the world's most liquid stock markets? In an analogous situation, note that the US economy does not appear to suffer significantly from the fact that we have not fully converted to the metric system of measures.

Commentary: The issue is not whether the US has the most liquid markets, it is whether decimalization can make these markets more liquid.

2.3 Competitiveness

Decimalization may have substantial effects on markets if the switch to decimal prices significantly decreases the size of the tick. The tick affects both the competition among traders within a market and the competition among markets to serve traders.

Argument in favor: The present tick limits the prices that traders can quote and therefore restricts price competition among traders. Traders cannot improve the best bid or offer when the spread is just one tick. A smaller increment would lead to smaller bid-ask spreads, especially in stocks with one-tick spreads. Since market orders submitted by small traders typically trade at the best quoted price, tighter spreads will lower transaction costs for small market order traders. Trading volumes should increase with lower transaction costs.

US markets will be more competitive relative to foreign markets, especially in cross-listed securities like Canadian stocks and ADRs. A small tick would solve arbitrage problems associated with currency rate translation. More foreign stocks would list in the US if our markets were more similar to their local markets.

If spreads narrow, order flow will be less valuable to dealers. The payments that some dealers make to brokers to attract their order flows will therefore decrease.

Argument against: Security markets have a minimum price increment for the same reasons that all oral auctions do. The increment keeps the market moving and it requires traders to make an economically significant contribution to price if they are to obtain precedence over other traders. In auctions for cars, art works, tobacco, farm machinery and real estate, the market organizer typically sets the minimum increment. Why not also in the securities markets?

Spreads provide information only about the cost of trading a quoted number of shares. If a decrease in the tick lowers the number of shares in the quotation, the market may be less liquid even if spreads narrow. The following argument explains why quoted size depends on the tick.

A smaller tick makes it easier for traders to step in front of one another at order-driven exchanges. This change favors traders who can see the order flow and who can react most quickly to price changes. Dealers and other professional traders are such traders. A decrease in the tick will therefore shift power from public traders to professional traders.

Exchanges use price, time, and public order precedence rules to arrange trades. The price rule gives precedence to the buyers who bid the highest prices and to the sellers who offer the lowest prices. At a given price, the time and public order rules give precedence to the traders who first display their willingness to trade at that price, and to public orders over member orders. These rules protect public limit order traders from front-running by dealers and by professional traders. They also encourage traders to display their orders early. When the tick is too small, the time and public order precedence rules are not meaningful. Any trader who wants precedence merely improves price by a trivial amount.

For example, suppose Public Trader L places a limit buy order at 30. When the tick is one cent, Professional Trader P can easily front-run this order by bidding 30.01. If a seller then arrives, P buys what L would have bought. If price rises a dollar, P will profit instead of L. If price falls a dollar, P will sell to L at 30. Trader P will lose only one cent and L will lose 99 cents. The public trader loses either way. The cost to the professional trader of playing this game is the tick he loses if prices fall.

Public traders defend themselves from front-runners by using floor brokers to hide their orders, by breaking up their orders, and by switching to market order strategies from limit order strategies. These responses increase their transaction costs, lower displayed sizes, and reduce market transparency.

The long-term effects of these responses can hurt both sides of the market. In the example above, the seller received a higher price because Professional Trader P stepped in front of Public Trade L’s order. But if L had not shown the order or if L had submitted a market order instead, P would not have bid at 30.01 and there would have been no buy order at 30. The seller might not have received even 30.

A decrease in spreads may cause dealers to exit. Liquidity might drop as a result.

If the tick does not vary by price level, corporations can adjust relative tick size by splitting their stock. For example, if the minimum price increment changes from 1/8 to 0.05, a 5:2 stock split will keep the tick constant in percentage terms. If issuers like the markets as they are, a change in tick size will impose unnecessary costs upon them.

Commentary:

At the NYSE, public limit orders almost exclusively determine spreads in the most actively traded securities. Specialists rarely trade these stocks because they must yield to public orders. Narrower spreads will not hurt these specialists because they now act more like brokers than like dealers. Narrower spreads will hurt their regional and third market competitors, who are largely unconstrained by their limit order books. These dealers will pay less for order flow, and they may even be forced out of business.

A smaller tick will tighten spreads in Nasdaq only if traders compete on quoted price to obtain order flow. Presently, most dealers do not compete on price because they have little incentive to do so without a time precedence rule. A dealer who improves price does not get much more order flow because all other dealers will match the price for their clients. Brokers route most retail orders to dealers by prearranged preferencing agreements. Dealers compete on the payments for order flow they make to brokers to obtain their order flows.[2]

Nasdaq spreads will narrow if public limit orders have sufficient precedence to compete effectively with dealers. The new limit order exposure rules now being implemented in Nasdaq are a step in this direction. If public limit order traders are able to narrow spreads, dealer payments for order flow will decrease and order preferencing arrangements will weaken. A decrease in payments for order flow, however, will increase retail commissions.[3]

Only traders who use market orders benefit from narrower spreads. Narrower spreads hurt public traders who use limit orders. This is especially true if a smaller tick makes it harder for them to compete with professional traders.

---

[2] Battalio and Holden (1996) provide a theoretical model with implications for the relation between the minimum price increment and payments for order.

Market orders often trade at better than quoted prices in exchange-listed stocks. This phenomenon is called price improvement. If spreads narrow, the rate of price improvement will likely decline.

Even when the spread is one tick, it is possible for a trader to offer a better price. Those that do simply trade immediately. If they are willing to trade a large order, they will improve price. For example, suppose the market is 20 bid and 20 1/8 offered. A buyer who offers a limit order at 20 1/8 will trade with whomever is offering to sell. If the order is large, it may take all size offered at 20 1/8 and the remainder of the buy order will establish a new bid at 20 1/8.

3. Empirical Evidence

The question of how usage costs differ in fractional versus decimal systems has not been studied nor has any effort been made to quantify how the pricing system affects market image. Given that the decimal and fractional systems are both actively used, it is unlikely that any cost differences are obviously greater than the costs of changing. If they were, all markets would have already adopted the lower cost system.

Several sets of studies provide empirical results that address the competitive issues. These studies show how trader behavior varies with the minimum price increment, or tick size. Since the economic importance of the tick depends on its size relative to price, these studies all examine relative tick sizes. The **clustering studies** examine how traders use the sets of prices available to them. The **time-series studies** examine how traders respond to tick size changes in a given security. Finally, the **cross-sectional studies** examine the extent to which differences in relative tick size across stocks and markets can explain differences in trader behavior and market quality.

3.1 Clustering Studies

Clustering studies examine how traders use the prices available to them. When the tick is a small fraction of price, traders do not uniformly use all fractions. For example, in the US stock markets, traders use whole numbers more often than halves, halves more often than odd quarters, and odd quarters often more than odd eighths.[4] Similar results appear in decimal markets like

[3] Harris (1996b) presents the economics underlying payment for order flow and order preferencing arrangements.
[4] Harris (1991b) Figure 1 and Furbush and Smith (1996).

gold, silver futures, foreign exchange, and Australian stocks.[5] There the clustering is on tens and fives. Interestingly, it also appears on 25s, which suggests that traders have a natural affinity for fractions based on powers of two. When the tick is a large fraction of price, traders use all fractions equally.

These results suggest that traders often choose to use a larger price increment than the minimum increment, if the latter is too small. A desire to reduce transaction costs may explain the result.[6] A limited price set decreases the costs of negotiating by limiting the number of potential offers and counter-offers. It also reduces the amount of information that traders need to exchange and therefore also the potential for misunderstanding. The tick cannot be too large, however. A large tick may limit trade when trader valuations are very close. For example, if a buyer is willing to pay no more than 4.04 and a seller is willing to accept no less than 4.01, then no trade can take place if the tick is 0.05. This hypothesis has three significant predictions: Traders should use smaller increments when asset values are well known, traders should use larger increments when the market is volatile, and traders should use larger increments when trading face-to-face as opposed to anonymously. Studies have confirmed each of these predictions using data from various sources.

3.2 Time-Series Studies

Analysts study the effect of tick size on traders by examining stocks for which the tick has changed. Three events change tick sizes. First, the minimum price increment rule may change. Second, a price may rise or fall across a threshold that separates one tick size from another. For example, when a Tokyo stock rises from 999 yen to 1000 yen, the tick increases from one yen to 10 yen. Finally, a stock may split so that the tick size, expressed as a fraction of price, changes because the price level changes.

Analysts have studied all three event types. Rule changes have been extensively studied. Price transitions have only been slightly studied. Stock splits have been extensively studied, but usually for the purpose of examining other issues than tick size.

---

[5] See Ball, Torous and Tschoegl (1985) for gold, Brown, Laux and Schachter (1991) for silver, Goodhart and Curcio (1992) for foreign exchange, and Aitken, Brown, Buckland, Izan and Walter (1995) for Australian stocks.
[6] Harris (1991b).

3.2.1 Evidence from Minimum Price Increment Rule Changes

Several studies examine recent decreases in the minimum price increments at the Toronto Stock Exchange, the American Stock Exchange, the Stock Exchange of Singapore and the Australian Stock Exchange. Unfortunately, these exchanges are all order-driven exchanges in which time-precedence encourages traders to improve price. Trading in this type of market is especially sensitive to tick size because the tick determines the cost of obtaining precedence through price when a trader does not have time precedence. The results of these studies are therefore most useful for predicting how decimalization might affect other order-driven exchanges like the NYSE and AMEX. They are much less useful for understanding how tick size affects dealer networks like Nasdaq that do not have time precedence rules.

3.2.1.1 The Toronto Stock Exchange

On April 15, 1996, the Canadian stock exchanges changed from mixed decimal and fractional pricing to pure decimal pricing. The exchanges also reduced the minimum tick from 1/8 dollar to 5 cents for stocks trading above 5 dollars. For stocks priced between 3 and 5 dollars, they reduced the tick from 5 cents to 1 cent. For stocks priced below 3 dollars and below 50 cents, the tick remained unchanged at 1 cent and ½ cent, respectively.

Six studies compare market quality at the Toronto Stock Exchange before and after the change. Tables 1 and 2 summarize their primary results concerning quoted bid-ask spreads and quotation sizes.

Spreads

For stocks priced between 3 and 5 dollars, spreads changed very little when the tick decreased to 1 cent.[7] The average spread for these stocks is about 11 cents. The former 5 cent tick apparently was already adequately small.

For stocks priced above 5 dollars, the studies report declines in average quoted spreads of from 2 to 5 cents per share. The results vary primarily because of differences in averaging methods. The smallest estimate is for an equal-weighted average. This averaging method gives most weight to the numerous infrequently traded stocks that tend to have large spreads. Before the rule change, the average spread for these stocks was 33 cents, or more than 2.6 ticks. These

[7] Bacidore (1997) Table 2, Huson, Kim and Mehrotra (1997) Table 1, and Weaver (1997) Table 2.

spreads did not decline much because the spreads were much larger than the tick. The largest reported decline in quoted spreads is for a volume-weighted average. This averaging method gives most weight to actively traded stocks that tend to have small spreads. The corresponding average spread was only 16.6 cents before the rule change, which is just larger than the minimum possible spread of 1/8 dollar.

Among the stocks priced above 5 dollars, the studies find that the greatest changes in spreads are for the lower price stocks and for the higher volume stocks. These stock characteristics are associated with low spreads. The former minimum price increment apparently was too large for traders in these stocks.

Four of the six studies examine how quickly spreads declined.[8] They all find that spreads narrowed immediately after April 15 and then stayed relatively constant at their new levels. Since these studies only examine data collected within five months of the rule change, they cannot provide evidence about the long-term effects of the tick change. It appears unlikely, however, that the long-term effects will be much different from the immediate effect.

Three studies compute average changes in spread classified by whether the Canadian stock was cross-listed for trading in the United States.[9] Spreads in the cross-listed stocks decreased slightly more than spreads in the other stocks. Although the difference may be due to more aggressive competition for order flow by Toronto traders, it is more likely due to the larger average size of the cross-listed stocks. The cross-listing difference is not statistically significant in an analysis that takes into account differences in trading activities and price levels.[10]

Two studies consider whether the Canadian decimalization had any effects on spreads in the US markets for cross-listed Canadian stocks.[11] At the NYSE, spreads did not change in the Canadian stocks.[12] In Nasdaq, spreads in the Canadian stocks dropped by 5 cents. The NYSE spreads for Canadian stocks were significantly higher on average than the TSE spreads for the same stocks, both before and after decimalization. In contrast, the Nasdaq average spreads were essentially identical to the TSE spreads before and after decimalization. The different results may

---

[8] Ahn, Cao and Choe (1997) Figure 1, Bacidore (1997) Figure 1, Huson, Kim and Mehrotra (1997) Table 1, and Ricker (1997) Exhibit V.

[9] Ahn, Cao and Choe (1997), Bacidore (1997) and Chung, Kryzanowski and Zhang (1997).

[10] Ahn, Cao and Choe (1997) Table 7.

[11] Ahn, Cao and Choe (1997) Tables 2 and 5 and Chung, Kryzanowski and Zhang (1997) Table 4.

be due to the different US market structures, but they are more likely due to differences in firm size: The NYSE-listed Canadian stocks are larger than the Nasdaq-listed Canadian stocks.

The effect of decimalization on spreads may vary by whether the stocks trade in the TSE CATS system or in the TSE Floor system. CATS maintains strict price-time precedence. The Floor system gives time precedence only to the first trader to arrive at a given price. All subsequent traders at that price share precedence on a pro-rata basis. Since it is easier to trade at a given price in the Floor system than in the CATS system, a smaller tick should affect price competition more in CATS than in the Floor system. The results of the one study that examined this issue show that spreads in the Floor system declined by more than spreads in the CATS system.[13] The result may be due to differences in stock characteristics between the two systems. Although the study provides no formal test, the difference does not appear to be statistically significant.

Another study shows that spreads decreased most for the above five dollar stocks for which spreads were equal to the minimum 1/8 dollar tick.[14] The median decrease in spreads for these stocks was 51 percent versus 30 percent for the other stocks.[15]

Quoted spreads can be poor indicators of liquidity conditions when many trades take place between the quoted prices. Since the tick sets the number of possible prices within a given spread, a small tick may effect market quality even without affecting the quoted spread. To address this issue, all six studies examine the average absolute difference between the trade price and the midpoint of the corresponding bid and ask prices. Twice this difference is called the effective spread. The effective spread results are similar to the quoted spread results. This indicates that price improvement at the TSE was not common either before or after the rule change. Before the rule change, only 8 percent of all trades were within the quoted prices. This increased only to 11 percent following the change.[16] Since price improvement is much more

[12] The authors use a control sample of comparable NYSE listed non-Canadian stocks to adjust the results for the influence of other factors that might have affected all spreads.
[13] Weaver (1997) Table 4.
[14] Chung, Kryzanowski and Zhang (1997) Table 3.
[15] Although the result is consistent with those reported above for the most actively traded stocks, it may not be reliable. Table 3 reports that the average pre-decimalization spread for the above $5 stocks that were quoted more than 95 percent of the time at 1/8 dollar is 11.7 cents. Since the lowest this mean could be is 12.5 cents, either an error of transcription or an error of calculation took place.
[16] Ricker (1997) Exhibit XII.

common in US exchange-listed stocks, these results suggest that the TSE experience may not generalize well to the US markets.

Quoted Size and Market Depth

A narrow spread does not indicate a liquid market if the number of shares that traders can trade at the quoted prices is small. For large traders, depth is more important than width. Accordingly, all six of the studies examine how average quotation size changed following the rule change.

Quotation sizes decreased slightly for stocks priced between 3 and 5 dollars (Table 2). The decrease is small and might easily have been due to other causes. For stocks priced over 5 dollars, the studies report average declines in quotation size that range from 26 to 52 percent. The variation is due to differences in samples and averaging methods. The greatest decreases are for stocks that are cross-listed at the NYSE. These stocks are the most actively traded stocks and the ones that experienced the greatest decline in spreads. When the results are adjusted for differences in trade frequency, the difference between NYSE cross-listed stocks and the not cross-listed stocks essentially vanishes.[17]

In all markets, a natural relation exists between quotation spread and quotation size. As a rule, the greater the spread, the greater the size since traders will be willing to sell more at a higher price and buy more at a lower price. A decrease in quotation size therefore does not necessarily indicate less depth when the spread narrows. For example, suppose traders are willing to buy 5 lots at 20.05 and 5 more lots at 20. If 20.05 is a feasible price, the best bid will be 20.05 for 5 lots. Otherwise, the best bid will be 20 for 10 lots.

Since the TSE reports size at each of the best five prices, it is possible to compute a better measure of depth than size at the best quote. For example, given the size displayed at various prices, an analyst can determine the size of an order that would move prices one percent. It would be interesting to determine whether this broader measure of depth changed following decimalization. Unfortunately, no study has done this analysis yet. Two studies, however, examine the ratio between size and spread at the best quote. This ratio provides a crude estimate

[17] Ahn, Cao and Choe (1997) Table 7.

of the size of an order that would move prices one percent.[18] The results are mixed with some analyses showing increases in the ratio and others showing decreases.[19] The differences depend on the stock sample examined and on the averaging method used. In any event, it seems that the results easily could be due to unrelated factors.[20] Although the results are not reliable, they suggest that depth broadly defined did not decrease as much as did size at the best price.

Markets are often deeper than they appear because traders do not always display their willingness to trade. We observe hidden size when a trade takes place that is larger than the prevailing quotation size. One study examined these events and determined that traders hid more size following decimalization than before.[21] This result suggests that the decline in quoted size overestimates the effect of decimalization on liquidity. It also suggests, however, that traders may be more concerned about front-running when the tick is smaller. It may also indicate that floor dealers more often step in front of the book when the tick is small by augmenting size at the best quote.

Trading Volumes and TSE Market Share

If transaction costs decreased at the TSE, TSE trading volumes and market share should both have increased. No study, however, finds significant changes in these variables.[22] The results on trading volumes are mixed, but generally indicate a minor decrease in volumes. The decrease is not large enough to distinguish from other causes of volume fluctuations. TSE market share also does not show any significant variation. If anything, market share trends down slightly during the sample period for the 5 to 10 dollar stocks for which decimalization has the greatest effect on spreads.[23] These results suggest that decimalization has not significantly affected TSE transaction costs, or that investors in Canadian stocks are not price sensitive in the short-run.

---

[18] This interpretation of the ratio assumes that relation between total size and price is linear. The ratio is a crude estimate its numerator and denominator are both quite noisy.
[19] Bacidore Table 8 and Ricker Exhibit XIII.
[20] Many factors cause quotation sizes and spreads to vary through time. In general, variation in quotation sizes is greater than in quotation spreads. This makes these analyses of quoted size less reliable than the corresponding analyses of quoted spreads. Since Baciodore adjusts for variation due to other factors, his result are probably more reliable than Ricker’s.
[21] Ricker (1997) Exhibit XIV.
[22] Ahn, Cao and Choe (1997) Tables 5 and 6, Bacidore (1997) Table 9, Huson, Kim and Mehrotra (1997) Table 4, Ricker (1997) Exhibit XII, and Weaver Table 12.
[23] Huson, Kim and Mehrotra (1997) Table 4.

Other Transaction Cost and Trader Profitability Estimates

Several studies examine other measures of transaction cost and trader profitability besides quoted spreads, effective spreads, quoted depths, and volumes. These measures include the Huang and Stoll (1996) adverse selection estimator,[24] measures of volatility,[25] and measures of dealer profitability inferred from TSE proprietary information about trader identities.[26] The results are generally too noisy to allow meaningful inferences. The noise is due to the poor quality of these estimators, to the short sample periods, and to other factors that may reasonably explain the results.

Decimalization did not significantly affect TSE seat prices.[27] This evidence indicates that traders did not expect that that the rule change would significantly impact dealer profitability.

Internalized and Crossed Trades

Two studies examine trade internalization rates and crossed trades.[28] An internalized trade is one in which a member firm trades with its client. A cross is a trade among a member firm's clients. The smaller tick may have two effects on the internalization rate. By lowering spreads, it decreases the value of internalization to the member. This should lower the internalization rate. Conversely, a smaller tick facilitates internalization by lowering the cost to the member of stepping in front of the book. This should raise the internalization rate. No theory predicts the effect of tick size on crosses. The empirical results are inconsistent and generally insignificant. Tick size does not significantly affect internalization and crossed trade rates.

The Ratio of Quotations to Trades

The ratio of the total number of quotations to the total number of trades increased by 10 percent following decimalization.[29] This increase suggests that negotiating trades may be more expensive when the tick is small, as suggested above. It may also indicate a greater degree of price competition among traders.

---

[24] Bacidore (1997) Table 7.
[25] Ricker (1997) Exhibit XII and Weaver (1997) Tables 7 and 8.
[26] Weaver (1997) Tables 10 and 11.
[27] Huson, Kim and Mehrotra (1997) Figure 3.
[28] Ricker (1997) Exhibit XII and Weaver (1997) Table 9.
[29] Ricker (1997) Exhibit XII.

3.2.1.2 Rule Changes at Other Stock Exchanges

The American Stock Exchange

On September 3, 1992, the AMEX reduced its minimum price increment from 1/8 to 1/16 dollar for stocks priced between one and five dollars. Two studies examine the effects of this change on market quality. Using somewhat different samples and methods, both studies show that average quoted spreads decreased by about 1.7 cents (10 percent) for the affected stocks.[30] The decreases were greatest for the more actively traded stocks among this largely inactively traded group. For the most active third of the stocks, spreads narrowed by 2.9 cents (19 percent).[31] Not surprisingly, the lowest price stocks also had the largest percentage decreases.[32]

Effective spreads also decreased, but the decrease (1.3 cents) is slightly smaller than for quoted spreads.[33] The difference between the quoted and effective spread results suggests that traders received less price improvement on average following the change in tick size. The fraction of trade prices strictly within the quoted spread, however, increased from 14.2 to 18.8 percent.[34] If the typical price improvement is one tick, these fractions imply a difference of 0.6 cents between the changes in the two spread types.[35] This is close to the actual difference of 0.4 cents. These results suggest that traders received price improvement more often, but on average the improvements were smaller.[36] This pattern is consistent with dealers taking small steps in front of their books more often.

Both studies analyze quotation sizes and volumes. Average quotation sizes decreased 9 percent and volume essentially did not change.[37] The results are weak, however, and the studies provide no formal significance tests.

---

[30] Ahn, Cao and Choe (1996) Table II examines data from June – November 1992 and Crack (1995) Table 2 examines data from January – December 1992.
[31] Ahn, Cao and Choe (1996) Table III. The least active of these "active" stocks traded only 4.9 times per day on average.
[32] Ahn, Cao and Choe (1996) Table IX.
[33] Ahn, Cao and Choe (1996) Table VI.
[34] Crack (1995) Table 4.
[35] The implied difference is computed as 0.142 (12.5) - 0.188 (6.25) = 0.6 cents.
[36] The spread results and the price improvement frequency results unfortunately come from different samples. The results therefore may not be strictly comparable.
[37] Ahn, Cao and Choe (1996) Table VII. To control for other factors that may affect these variables, the reported mean changes are adjusted by the corresponding means computed from the NYSE one to five dollar stocks. Although the adjustment is appropriate, it would have been better if the NYSE stocks were also matched on firm size. Since Crack's analysis does not control for other factors, his results are less reliable.

Traders used odd sixteenths for only 13 percent of their transactions in the four months following their introduction in 1992.[38] Had they used all sixteenths uniformly, the odd sixteenth usage rate would have been 50 percent. The odd usage frequency has since increased. During the week of March 16, 1997, one to five dollar AMEX stocks closed on an odd sixteenth 35 percent of the time.[39] The contrast between the 1992 and 1997 results suggests that the full effect of the rule change was not immediately realized. Unfortunately, no study has examined recent AMEX bid-ask spreads for these low price stocks.

The American Stock Exchange extended the 1/16 dollar minimum price increment to all stocks priced under 10 dollars in February 1995. The effects of this change have yet not been studied.

The Stock Exchange of Singapore

On July 18, 1994, the Stock Exchange of Singapore reduced the minimum price increment from 50 cents to 10 cents for stocks priced over 25 dollars. The rule change affected only five stocks, of which only three traded substantially both before and after the change. Quoted bid-ask spreads for these stocks decreased by an average of 40 percent in the five days following the rule change.[40] Quotation sizes at the best bid or offer decreased by an average of 70 percent but the total displayed size at all prices decreased by only 50 percent. There was no apparent change in volume. Although the small sample size makes the results unreliable, the smaller decrease in total size than quoted size is notable. It suggests that the decrease in quotation size presented in the Toronto and AMEX studies overestimates the total effect of smaller ticks on depth.

The Australian Stock Exchange

On December 4, 1996, the Australian Stock Exchange reduced the minimum price increment for stocks priced under 50 cents and for stocks priced over 10 dollars. The tick decreased from 1/2 cent to 1/10 cent for 84 stocks priced under 10 cents, from 1 cent to 1/2 cent for 234 stocks priced between 10 and 50 cents, and from 2 cents to 1 cent for 14 stocks priced between 10 and 50 dollars. A very preliminary (and unreleased) study examines trading in the 60

---

[38] Crack (1995) Section 4.1.4.
[39] Personal communication with Ryan Ciociola, American Stock Exchange research analyst.
[40] Lau and McInish (1995) Table 2.

days surrounding the rule change.[41] Quoted spreads declined 26 percent and 10 percent respectively for stocks priced under 10 cents and between 10 and 50 cents. Spreads for the 14 higher price stocks increased by 26 percent. This result is probably not reliable given the small sample size. The results concerning depth are not consistent. On balance, it appears that depth declined.[42] The latter results are especially interesting because the study measures depth by the dollar amount necessary to move price one percent. The study computes depth from an analysis of the complete limit order book and not just from size at the best bid and offer. The observed decrease in depth shows that traders were less willing to expose size at or within one percent of the best price when the tick became smaller.

3.2.2 Evidence from Price Transitions

The minimum price increment for a stock changes discretely when its price rises or falls through a price threshold that separates one tick size from the next. The effect of tick size on market quality can therefore be studied by examining stocks that made these transitions.

One study uses this method in an analysis of 26 Paris Bourse stocks that traded on two different ticks during January and February 1995.[43] Most of the stocks traded near 500 francs. The tick size above 500 francs is 1 franc; below it is 0.1 franc. The results show that quoted spreads were 12 percent smaller on average when the stocks traded on their smaller tick than on their larger tick. Average quotation sizes (at the best prices) were 46 percent smaller and the average ratio of quotation size to spread was 35 percent smaller on the smaller tick. There was no significant difference in volumes, however.

The Paris Bourse allows traders to place limit orders that display only a portion of their full size. An analysis of this feature of the Paris market therefore permits direct inferences about how traders respond to smaller ticks. When the stocks traded on the smaller tick, traders restricted the display of 43 percent of their orders. In contrast, they restricted the display of only 37 percent of their orders when the stocks traded on the larger tick. These fractions, and the differences between them, increased with the size of the order. They suggest that traders are reluctant to show orders when the tick does not provide much protection from front-runners.

---

[41] McInish and McCorry (1997) Table 2.
[42] The ambiguity is probably due to data coding problems that appear to affect the results in this preliminary (and unreleased) version of the study.
[43] Harris (1996a) Table VII.

3.2.3 Evidence from Stock Splits

Since the tick is a constant 1/8 dollar for most US stocks, the tick expressed as a fraction of price decreases following a stock split in inverse proportion to the split factor. Studies of split stocks therefore can provide useful information about the effect of tick size on market quality.

Several studies of US stock splits have examined how spreads and volumes change following stock splits.[44] These analyses uniformly show that relative bid-ask spreads widen following stock splits.

The results on trading volumes generally show that dollar volumes decline, but these results are not uniform across samples. The change in the dollar value of the even lot size and the information released by the split announcement may influence the volume results.

No study has yet examined the effect of splits on quotation sizes.

3.3 Cross-Sectional Studies

Tick size, measured as a fraction of price, varies substantially across stocks and markets. The effects of tick size on market quality can therefore be studied by comparing stocks that trade on relatively small ticks to those that trade on larger ticks. Several studies pursue this strategy.

3.3.1 US Stock Exchanges

Since most US exchange-listed stocks trade on a 1/8 dollar tick, relative tick size is large for low price stocks and small for high price stocks.

Spreads and Quotation Sizes

Bid-ask spreads, measured as a fraction of price, are smaller for high price stocks than for low price stocks.[45] In 1989, the average spread for US exchange-listed stocks priced over 40 dollars was 0.44 percent of price. For stocks priced under 10 dollars, it is 3.5 percent of price. Much of the difference is due to the fact the higher price stocks are larger, more actively traded stocks for which we would expect lower spreads. However, after adjusting for various characteristics that vary among the stocks, spreads are still wider when the relative tick is large. This result is primarily due to the fact that spreads can be no smaller than the minimum price increment. For the under 10 dollar stocks, quoted spreads were equal to 1/8 dollar 67 percent of

---

[44] Copeland (1979), Masson (1985), Conroy, Harris and Benet (1990), Desai, Nimalendran, and Venkataraman (1994) and Arnold and Lipson (1996).

[45] Harris (1994), Table 1.

the time. They were 1/8 dollar only 33 percent of the time for the above 40 dollar stocks. Even after further adjusting for the effects of price discreteness, the higher price stocks still have smaller spreads.

Quotation sizes depend on a number of factors, the most important of which is firm size. After controlling for the influence of these factors, quotation sizes are greatest for the low price stocks and for stocks that commonly have 1/8 dollar spreads. These results, taken together with the spread results noted above, show that traders quote tighter markets for smaller size when the relative tick is small.

Information from high price stocks for which the tick is a small fraction of price can be used to predict how low price stocks would trade if they could trade on smaller increments. For example, suppose the tick is lowered to 1/16 dollar for stocks priced under 10 dollars. The analyses suggest that spreads would decrease 38 percent, quotation sizes would decrease 16 percent, and daily volumes would increase 34 percent.[46] For stocks priced over 40 dollars, the effects would be much smaller. These predicted changes are larger than the changes actually observed in the four months immediately following the 1992 AMEX rule change.[47] No study has examined whether these effects grew through time as traders become more familiar with the using the smaller tick.

Limit Order Usage

When the tick is a small fraction of price, public traders may avoid using limit orders to hide their intentions from front-runners. An analysis of orders transmitted through the NYSE SuperDot order routing system shows that only 26 percent of all orders for stocks priced above 50 dollars are limit orders. In contrast, for stocks priced between 1 and 5 dollars, the limit order fraction is 46 percent.[48] Unfortunately, these results do not control for the size of the spread. When the spread is large relative to price, we also expect more limit order usage.

Whatever the reason, the greater use of limit orders when the relative tick is large demonstrates that the public supplies more liquidity when the tick is large than when it is small. Any presumption that a large tick benefits only dealers is not well founded.

---

[46] Harris (1994), Table 5.
[47] Crack (1995) Appendix B.
[48] Angel (1997) Table IV.

3.3.2 The Paris Bourse

The average relative tick size at the Paris Bourse is only one-tenth as large as it is in the US. In US exchange markets, spreads are typically 1, 2 and occasionally 3 ticks wide. At the Paris Bourse, the average spread is 35 ticks wide for small stocks and 12 ticks wide for large stocks.[49] The minimum price increment rarely constrains Paris bid-ask spreads.

Tick sizes vary by price level at the Paris Bourse. Broadly characterized, they are proportional to price level. The correlation between relative tick size and price level therefore is not as great as in the US.

Spreads and Quotation Sizes

At the Paris Bourse, no correlation exists between relative bid-ask spread (spread as a fraction of price) and relative tick size (tick as a fraction of price).[50] The tick is apparently too small to have much effect on spreads.

Tick size does affect quoted size.[51] Traders display more size on average in stocks with large relative ticks. The average ratio of quotation size (at the best prices) to the relative spread is also larger for larger relative ticks. Perhaps most interestingly, the average ratio of block size to the block spread is also larger. The block spread is the difference between the prices at which standard sized block purchases and sales would trade. Since it is computed from the displayed order sizes at and behind the best prices, the block spread is a very good measure of market depth for large trades. These results show that traders are less willing to display order size when the tick size is small.

Undisplayed Limit Order Size

The Paris Bourse allows traders to place limit orders that display only a portion of their full size. Analysts therefore can directly observe the extent to which traders hide size when the relative tick size is small. When the relative tick is between 2 and 5 basis points, traders restrict display for 79 percent of their larger orders (orders larger than 500,000 francs or about US$100,000).[52] When the relative tick is between 20 and 50 basis points, traders restrict display

[49] Harris (1996a) Table I.
[50] Harris (1996a) Table V. This result is obtained after adjusting for the effects of stock characteristics like firm size.
[51] Harris (1996a) Table V.
[52] Harris (1996a) Table III, Panel B.

for only 50 percent of their larger orders. The analysis finds similar results for the smaller orders, although traders display smaller orders more often than larger ones. These results show that traders are less willing to display size when other traders can easily step in front of their orders.

Traders in the Toronto CATS system can also display only a portion of their full order size. The average relative tick size at the TSE, however, is about 12 times larger in Toronto than at the Paris Bourse.[53] Not surprisingly, CATS traders display much more of their orders. They restrict display for only 13 percent of their larger orders. In contrast, traders at the Paris Bourse restrict size for 74 percent of their comparable orders.[54] These results are consistent with results (cited above) that show that traders displayed less size following the Canadian decimalization.

3.3.3 Two Notable Empirical Regularities

Two notable empirical regularities characterize US stock prices. First, average stock price levels have remained essentially constant for the last 70 years despite a 10-fold increase in general price levels and a 25-fold cumulative return on equities. Second, price levels are strongly correlated with firm size. Small stocks have low prices and large stocks have high prices. The obvious fact that small firms get big when their prices go up does not adequately explain this correlation. These stock price regularities are largely peculiar to the United States. They are not found to the same degree in other national markets.

Price levels have remained constant because firms split their stock when prices get "too" high. At first glance, no obvious reasons explain why firms should split their stocks, and no rules require that they do so. Warren Buffett, for example, refuses to split Berkshire Hathaway's stock even though it now trades at just under $40,000 per share. Arguments in favor of splitting to maintain the affordability of the even lot size cannot explain why the lot size in real inflation-adjusted terms has been continuously declining.

Three authors suggest that firms split their stocks to control the size of the relative tick.[55] This control is possible in the US because the tick is a constant 1/8 for all prices above one dollar. Since most other markets have tick schedules for which the tick increases in proportion to price

[53] Harris (1996a) Table I.
[54] Harris (1996a) Table III, Panel A.
[55] Harris (1994), Anshuman and Kalay (1994) and Angel (1997).

levels, firms cannot control tick size to the same degree. Firms in such markets split less than in the US.

Firms presumably split their prices to obtain a relative tick that produces the best market quality for their stocks. Since market conditions are different for small stocks than for large stocks, the optimal relative tick size will vary by firm size. This observation can explain the persistent correlation between firm sizes and prices in the US.

Angel (1997) constructs a compelling empirical case for this theory based on a set of carefully organized international comparisons of markets with various tick schedules. If correct, the theory predicts that a uniform decrease in tick size will eventually lead to lower price levels.

4. Limitations and Suggestions for Further Research

Existing empirical studies of the effect of tick size on market quality leave several important questions unanswered. Perhaps most importantly, we know nothing about the effect in dealer markets. Tick size probably affects dealer markets less than exchange markets because the former do not enforce time precedence rules. This conjecture needs to be confirmed. The topic is especially important because many decimalization proponents hope that a decrease in tick size will affect order preferencing arrangements in dealer markets.

We also know nothing about the long-term effects of tick size changes. The studies surveyed here examine data only out to one-half year at most. The effect, if any, of tick size on trading volumes may take especially long to observe. Volumes should change if trading costs change, but it may take a long while before traders recognize a change in trading costs. Longer samples must be studied to determine how long traders require to adjust to a new tick size.

With a few exceptions, the studies do not adequately account for factors other than tick size that affect spreads, quotation sizes and volumes. The analyses need to be much more sensitive to differences in stock characteristics and to the normal variation of market quality variables through time. These concerns are especially important for long-term studies and for studies that contrast markets.

Studies of how market quality changes when a stock transitions from one tick size to another as its price changes should provide very reliable information about tick sizes. Because these events occur often and at random points in time, statistical analyses of their effects will be powerful and largely immune from extraneous influences.

The effect of tick size on market quality may vary by the amount of quotation information that an exchange publishes. US exchanges publish only size at the best bid and offer prices. Exchanges like the Paris Bourse and the Toronto Stock Exchange publish size at and behind the best prices. Since tick size affects quotation sizes, a change in tick size may affect traders differently in these two types of markets. Since order exposure is very important to large traders, analysts should investigate this issue further.

We presently know very little about how variation in tick size schedules affects markets. In the US, for most stocks, the tick size schedule is flat at 1/8 dollar for all prices. (It soon will be a flat 1/16 dollar at AMEX.) In other countries, a schedule of tick sizes keeps them roughly proportional to prices. We need to better understand the empirical effect of these differences on stock splits and on the relation between price level and firm size.

References

Ahn, Heejoon, Charles Cao and Hyuk Choe, 1996, “Tick Size, Spread, and Volume,” *Journal of Financial Intermediation* 5(1), 2-22.

Ahn, Heejoon, Charles Cao and Hyuk Choe, 1997, “Decimalization and Competition among Exchanges: Evidence from the Toronto Stock Exchange Cross-Listed Securities,” Working paper, Pennsylvania State University, (January 1997).

Aitken, Michael, Philip Brown, Christine Buckland, HY Izan, and Terry Walter, 1995, “Price Clustering on the Australian Stock Exchange,” Working paper, University of Western Australia, (August 1995).

Amihud, Yakov and Haim Mendelson, 1990, “Option Market Integration: An Evaluation,” Paper submitted to the US Securities and Exchange Commission.

Angel, James, 1997, “Tick Size, Share Prices, and Stock Splits,” forthcoming, *Journal of Finance* 52(2).

Anshuman, V. Ravi and Avner Kalay, 1994, “Can Splits Create Market Liquidity? Theory and Evidence,” Working paper, Boston College, (August 1994).

Arnold, Tom M. and Marc Lipson, 1996, “Stock Splits and the Execution of Limit Orders,” Working Paper, University of Georgia, (March 1996).

Bacidore, Jeffrey M., “The Impact of Decimalization on Market Quality: An Empirical Investigation of the Toronto Stock Exchange,” 1997, Working paper, Indiana University, (February 1997).

Ball, Clifford A., Walter N. Torous and Adrian E. Tschoegl, 1985, “The Degree of Price Resolution: The Case of the Gold Market,” *Journal of Futures Markets* 5(1), 29-43.

Battalio, Robert and Craig W. Holden, 1996, “Why Doesn’t Decimal Trading Eliminate Payment for Order Flow and Internalization,” Working paper, Indiana University, July 1996.

Brown, Sharon, Paul Laux and Barry Schachter, 1991, “On the Existence of an Optimal Tick Size,” *Review of Futures Markets* 10(1), 50-72.

Chordia, Tarun and Avanidhar Subrahmanyam, 1995, “Market Making, the Tick Size, and Payment-For-Order Flow: Theory And Evidence,” *Journal of Business* 68(4), 543-575.

Chung, Richard, Lawrence Kryzanowski and Hao Zhang, 1997, “Decimalization’s Winners and Losers,” *Canadian Investment Review* (Winter 1996/97), p. 35-39.

Conroy, Robert M, Robert S. Harris and Bruce A. Benet, 1990, “The Effects of Stock Splits on Bid-Ask Spreads,” *Journal of Finance* 45(4), 1285-1295.

Copeland, Thomas E. 1979, “Liquidity Changes Following Stock Splits,” *Journal of Finance* 34(1), 115-141.

Cordella, Tito and Thierry Foucault, 1996, “Minimum Price Variations, Time Priority and Quotes Dynamics,” Working paper, Universitat Pompeu Fabra, Ramon Trias Fargas, 25-27, 08005 Barcelona, Spain, September 1996.

Crack, Timothy Falcon, 1995, “Tinkering with Ticks: Choosing Minimum Price Variation for the US Equity Markets,” Working paper, Indiana University, (November 1995).

Desai, Anand , M. Nimalendran, and S. Venkataraman, 1994, “Changes in Trading Patterns Following Stock Splits and Their Impact on Market Microstructure: Theory and Evidence,” Working paper, Kansas State University, (April 1994).

Furbush, Dean and Jeffrey W. Smith, 1996, “Quoting Behavior on Nasdaq: the Effects of Clustering on Relative Spreads,” Working paper, National Association of Securities Dealers, April 1996.

Goodhart, Charles and Ricardo Curcio, 1992, “Asset Price Discovery and Price Clustering in the Foreign Exchange Market,” Working paper, London School of Business, (1991).

Harris, Lawrence, 1991a, “Liquidity, Trading Rules and Electronic Trading Systems,” *New York University Salomon Center Monograph Series in Finance and Economics*, Monograph 1990-4.

Harris, Lawrence, 1991b, “Stock Price Clustering and Discreteness,” *Review of Financial Studies* 4(3), 389-415.

Harris, Lawrence, 1993, “Consolidation, Fragmentation, Segmentation and Regulation,” *Financial Markets, Institutions & Instruments* 2(5), 1-28.

Harris, Lawrence, 1994, “Minimum Price Variations, Discrete Bid-Ask Spreads, and Quotation Sizes,” *Review of Financial Studies* 7(1), 149-178.

Harris, Lawrence, 1996a, “Does a Large Minimum Price Variation Encourage Order Display?” Working paper, Marshall School of Business at USC, (October 1996).

Harris, Lawrence, 1996b, “The Economics of Best Execution,” Working paper, Marshall School of Business at USC, March 1996.

Huson, Mark, Youngsoo Kim and Vikas Mehrotra, 1997, "Decimal Quotes, Market Quality, and Competition for Order Flow: Evidence from the Toronto Stock Exchange," Working paper, University of Alberta, (March 1997).

McInish, Thomas H. and Michael S. McCorry, 1997, "Reducing Tick Size on the Australian Stock Exchange," Unreleased working draft, University of Memphis, (March 1997).

McInish, Thomas H. and Sie Ting Lau, 1995, "Reducing Tick Size on the Stock Exchange of Singapore," *Pacific-Basin Finance Journal* 3, 485-96.

Peake, Junius W., 1993, "Brother Can You Spare a Dime? Let's Decimalize the U.S. Equity Markets!" Published in *Global Equity Markets: Technological, Competitive and Regulatory Challenges*, Robert A. Schwartz, Editor; Irwin: Chicago, 1995, p. 302-339.

Ricker, Jeffrey P., 1996, "Decimal Quotes: The Price is Right," Working paper, 1730 Filbert Street No. 105, San Francisco, CA 94123, (November 1996).

Ricker, Jeffrey P., 1997, "Decimal Pricing: Nickel Markets," Working paper, 1730 Filbert Street No. 105, San Francisco, CA 94123, (March 1997).

Seppi, Duane J., 1996, "Liquidity Provision with Limit Orders and a Strategic Specialist," Working paper, Carnegie Mellon University.

Wallman, Steven M. H., 1996, "Technology and Our Markets: Time to Decimalize," Speech presented to the Center for the Study of Equity Markets, Pace University, September 25, 1996.

Weaver, Daniel G., 1997, "Decimalization and Market Quality," Working paper, Marquette University, (March 1997).

Table 1

Changes in Toronto Stock Exchange Spreads Surrounding April 15, 1996

	Average Change in Quoted Spread	
	Cents	Percent
Ahn, Cao & Choe, February – June 1996		
Not cross-listed stocks above $5	-3.4¢	-17%
Cross-listed on NYSE above $5	-4.0	-27
Cross-listed on Nasdaq above $5	-3.8	-16
Cross-listed on NYSE above $5 *at NYSE*, measured relative to NYSE control sample	-0.3	0
Cross-listed on Nasdaq above $5 *at Nasdaq*, measured relative to Nasdaq control sample	-5.2	11
Bacidore, February 19 – June 7, 1996, excluding April 1-26.		
$1-3 stocks	0.6¢	10%
$3-5 stocks	0.8	9
Not cross-listed stocks above $5	-3.8	-20
Cross-listed stocks above $5	-3.7	-27
For above $5 stocks, the changes are greater for actively traded stocks and low price stocks.		
Chung, Kryzanowski and Zhang, February 2 – June 25, 1996, excluding April 5-22.		
Small Cap	n/a	-23%
Mid Cap	n/a	-32
Large Cap	n/a	-43
Former spread was 1 tick	n/a	-51
Former spread was above 1 tick	n/a	-29
Cross-listed stocks	n/a	-36
Cross-listed stocks, *US quotes*	n/a	-3
Huson, Kim & Mehrotra, February – September 1996		
$3-5 stocks, September versus March	-0.0¢	n/a
$5-10 stocks, September versus March	-5.9	n/a
$10-30 stocks, September versus March	-5.5	n/a
Above $30, September versus March	-4.8	n/a
Similar results are obtained for May, June, July and August contrasts with March with no obvious trend.		
Ricker, January – September 1996		
Above $5 stocks, equal-weighted average	-2.1¢	-6%
Above $5 stocks, volume-weighted average	-5.0	-30%
Before April 15, 23% of the stocks were quoted with the minimum $1/8 spread 75% of the time. Afterwards only 5% were quoted with the minimum $0.05 spread 75% of the time.		
Weaver, March and May, 1996		
$3-5 stocks, CATS	1.5¢	13%
$3-5 stocks, Floor	-0.1	-1%
Above $5 stocks, CATS	-1.7¢	n/a
Above $5 stocks, Floor	-3.5	n/a
In the floor system, the decrease in spreads is greatest for low price and high volume stocks. Similar results are found for CATS.		

Table 2

Changes in Toronto Stock Exchange Quotation Sizes Surrounding April 15, 1996

	Average Change in Quotation Size	
	Change	Percent
Ahn, Cao & Choe, February – June 1996		
Not cross-listed stocks above $5	-19 lots	-26%
Cross-listed on NYSE above $5	-68	-51
Cross-listed on Nasdaq above $5	-19	-26
Cross-listed on NYSE above $5 *at NYSE*, measured relative to NYSE control sample	- 2	-5
Cross-listed on Nasdaq above $5 *at Nasdaq*, measured relative to Nasdaq control sample	n/a	n/a
Bacidore, February 19 – June 7, 1996, excluding April 1-26.		
$1-3 stocks	-2 lots	-5%
$3-5 stocks	-6	-11
Not cross-listed stocks above $5	-24	-33
Cross-listed stocks above $5	-66	-52
Chung, Kryzanowski and Zhang, February 2 – June 25, 1996, excluding April 5-22.		
Small Cap	n/a	-21%
Mid Cap	n/a	-29
Large Cap	n/a	-40
Former spread was 1 tick	n/a	-53
Former spread was above 1 tick	n/a	-29
Cross-listed stocks	n/a	-37
Cross-listed stocks, *US quotes*	n/a	-1
Huson, Kim & Mehrotra, February – September 1996		
$3-5 stocks, September versus March	-1 lots	n/a
$5-10 stocks, September versus March	-21	n/a
$10-30 stocks, September versus March	-36	n/a
Above $30, September versus March	-17	n/a
Similar results are obtained for May, June, July and August contrasts with March with no obvious trend. The size differences are 2/3 smaller for the late April versus early April contrast, however.		
Ricker, January – September 1996		
Above $5 stocks, equal-weighted average	$-72,745	-39%
Above $5 stocks, TSE300 stocks only	-40,190	-44%
Weaver, March and May, 1996		
$3-5 stocks, CATS	-4 lots	-10%
$3-5 stocks, Floor	5	11%
Above $5 stocks, CATS	-16	n/a
Above $5 stocks, Floor	-28	n/a

Does a Large Minimum Price Variation

Encourage Order Exposure?

Lawrence Harris
University of Southern California

Lawrence Harris
Professor of Finance
School of Business Administration
University of Southern California
Los Angeles, CA 90089-1421

Voice: (213) 740-6496
FAX: (213) 740-6650
E-Mail: LHarris@USC.edu
Web: http://LHarris.USC.edu/

Version 1.02

April 17, 1997

The latest draft of this manuscript can be downloaded in Adobe Acrobat PDF format at http://LHarris.USC.edu/Acrobat/Hidden.PDF

The author would greatly appreciate suggestions and comments from any source.

The author expresses gratitude to several institutions and individuals for their assistance with this project. The Toronto Stock Exchange and the SBF Paris Bourse provided the data. The New York Stock Exchange, Inc. provided financial assistance. Didier Davydoff and Marianne Demarchi of the Paris Bourse and Meyer Beck, Pearce Bunting, Pina DeSantis, Roland Fleming and Jim Gallagher of the Toronto Stock Exchange provided the databases and explained their structure. Mark Carhart, Mendy Fygenson and Ananth Madhavan provided valuable comments on early drafts. Namrata Aggarwal, Jennifer Ly and especially Venkatesh Panchapagesan provided very able research assistance at USC.

ABSTRACT

Does a Large Minimum Price Variation Encourage Order Exposure?

The minimum price variation (tick) affects order exposure. Traders who display their orders risk being front-run. In markets that enforce time precedence, the tick makes front-running expensive. It sets the price of obtaining order precedence through price priority when another trader has time precedence. This paper examines order, quotation, and transaction data from the Paris Bourse and the Toronto Stock Exchange to characterize the relation between tick size and order exposure. The results show that traders display more size when the tick is large and when intraday volatility is small. The topic is particularly timely given recent regulatory interest in reducing tick sizes.

Key words: Minimum price variations, tick, time precedence, order transparency, order display, order disclosure, hidden orders, quotation sizes, electronic exchanges, front-running, order option values.

Does a Large Minimum Price Variation Encourage Order Exposure?

EXCHANGES AND BROKERS that use computer assisted trading systems to arrange trades are successful only if they can encourage traders to offer liquidity in their systems. Traders offer liquidity when they submit standing limit orders that indicate that they are willing to trade. Traders may publicly display these indications or they may only disclose them to the trading system. Without standing limit orders, these systems have no liquidity.

To be successful, trading systems must attract traders who demand liquidity. Liquidity demanders submit their orders to where they expect they will be filled. Where traders can see displayed liquidity, they can easily form these expectations. Where liquidity may be present but undisplayed, they form these expectations through experience generated by trial and error. Since liquidity is easier to find when it is displayed, and since some traders may trade only when they see an opportunity, the sponsors of trading systems want traders to fully display their orders.

Traders who offer liquidity, and especially those who display their offers, expose themselves to various risks. They risk trading with better informed traders (adverse selection). They also risk higher transaction costs if other traders employ front-running trading strategies to profit from the information conveyed by their exposure. Trading systems that force traders to expose their standing orders may drive those orders away.

Trading system designers therefore must balance two sometimes conflicting interests. They need to attract liquidity and they want traders to display that liquidity. If they force traders to display, they may not obtain the liquidity.

To encourage traders to offer liquidity, trading systems provide various facilities that allow traders to limit their order display. Virtually all systems permit traders to cancel orders on demand or at some prespecified time. Fill-or-kill, day, and good-till-canceled order instructions are examples of such facilities. Some systems, such as those used by the Paris Bourse, the Toronto Stock Exchange and Globex, also allow traders to specify only partial display of their orders. These systems hide the remaining size and display it only after the displayed size executes. In these systems, liquidity demanders learn about the undisclosed size only upon the presentation of a qualifying order that executes.

To encourage traders to display their orders (and to encourage order submission), most order-driven trading systems use secondary order precedence rules that reward traders for displaying their orders.[1] Time precedence rules encourage traders to display by giving the first orders submitted at a given price the right to trade first. In those systems that allow traders to partially disclose their orders, a display precedence rule gives precedence to displayed order size over undisplayed size at a given price.

The economic importance of secondary order precedence rules depends on the size of the minimum price variation, known in some markets as the tick.[2] If the tick is small, traders can use price priority to obtain precedence by just slightly improving price. A large tick makes front-running strategies expensive and should therefore encourage traders to expose their orders.

This study examines the empirical relation between order exposure and tick size. Using order data from the Paris Bourse and the Toronto Stock Exchange, the analyses characterize the trader propensities to control their order display. The results show that larger ticks are indeed associated with greater order display. Traders are also less likely to display in volatile stocks. Additional analyses show how the tick affects more general measures of market liquidity.

The results should interest exchanges, brokers, regulators, traders, and academics. Exchanges will be interested because they specify their minimum price variation schedules.[3] Brokers will be interested because traders who wish to control their order exposure often use brokers to hold them hidden. Regulators will be interested because they must estimate the social costs and benefits of regulating tick sizes and of enforcing universal time precedence across exchanges.[4] Traders will be interested because they must decide when and how to expose their orders. Finally, academics should be interested because we understand very little about how tick size and time precedence affect market quality.

The remainder of the paper is organized as follows: Section I provides a deeper

[1] Price priority is usually the first precedence rule. Price priority gives precedence to orders that offer the best prices (the lowest offers and the highest bids).
[2] The minimum price variation is the minimum amount by which prices can differ. All prices must be expressed as an integer multiple of the minimum price variation.
[3] The Toronto Stock Exchange and the American Stock Exchange have most recently changed their minimum price variation regulations.
[4] The Division of Market Regulation of the US Securities and Exchange Commission, for example, suggested in their Market 2000 Study (1994) that smaller minimum price variations be considered for adoption, as did SEC Commissioner Steven Wallman in a September 25, 1996 speech.

discussion of the issues involved, presents hypotheses, and cites related research. Section II describes the data. Section III provides an initial empirical characterization of how traders control their order display. Section IV presents cross-sectional characterizations of the propensity of traders to display orders, and of the relation between tick size and measures of market liquidity. Section V provides a time-series analysis of these issues for a subset of stocks that traded on two tick sizes during the sample period. The paper concludes in Section VI with a short summary and some suggestions for further research.

I. Theoretical Discussion, Testable Hypotheses and Prior Research

A. Economics of the Order Exposure Decision

The main reason traders display orders is to attract other traders. Traders who expose their orders risk that other traders will use this information to their disadvantage. Such traders may try to infer security values from the exposed order flow or they may try to take advantage of trading options implicit in the exposed order flow.

If the market suspects that a trader is well informed, price will move away from him when he exposes his order. Other traders will either front-run his order or they will refuse to supply liquidity to his side without a substantial price concession. This may happen regardless of whether the trader is indeed well informed.

Traders rarely know who is well informed because informed traders do not want to be identified. Traders widely believe that large anonymous traders are well informed. They base this conclusion on the observation that informed trading is most profitable when traders can trade large size with little price impact and on the presumption that large traders will invest more in information than will small traders. Traders also assume that aggressively priced orders may come from informed traders because impatient traders generally issue such orders.

Even if traders are uninformed, their order exposure can still adversely affect their trading costs. Orders provide free trading options to other traders. The value of these options can be extracted by clever traders called quote-matching front-runners.

For example, suppose that a quote-matcher knows that a large order to buy stock is at 20. If she can buy the stock before the large trader, she will acquire a valuable position in the stock. If stock values subsequently rise, she will profit to the full extent of the rise. If they fall, she may be able to bound her loss by selling to the large order at 20.

In practice, several factors may make it difficult to profit from this strategy. The quote-matcher may be unable to acquire her position without paying a substantial premium over 20. If she does acquire her position, she may be unable to sell out to the large order. The large order trader may cancel the order or adjust it downward to reflect a change in values. Although these (and other) factors make the quote-matcher strategy less profitable, they may not eliminate all potential profits. Quote-matching can be profitable if traders can identify and exploit significant inelasticities in the demand for liquidity.

The profits that quote-matchers make come at the expense of the order exposing traders. Quote-matchers take liquidity that might otherwise have gone to these traders. In the example, if the quote-matcher takes a trade away from the large trader, and if price subsequently rises, the quote-matcher profits are profits that otherwise would have gone to the large trader.

B. Defensive Strategies

Large traders and informed traders limit order exposure to minimize their losses to quote-matching front-runners. Traders control order exposure three ways. They have their agents manage exposure for them, they cancel and resubmit their orders, and they break up their orders.

In automated order matching systems, the system is the traders' agent. In systems that permit partial order exposure, traders specify how their orders should be displayed. Usually, some minimum quantity must be displayed. Liquidity demanders can discover undisplayed size only by committing to trading with it and with all displayed orders at the same price.[5] This mechanism greatly reduces the potential profits from quote-matching strategies by denying information to traders who are not otherwise interested in trading.

In manual trading systems, traders control their order exposure by instructing their brokers to expose only to traders who are likely to be interested in trading. (The instruction is usually implicitly assumed.) A good broker exposes orders only to traders who are likely to fill them, and avoids traders who would front-run them.

Traders can also cancel their orders frequently to control their order exposure. They may

[5] For example, suppose that a trader wonders whether there is undisclosed liquidity to sell at 30. To reveal it, he must place a limit buy order at 30 for more size than is displayed there. If the order trades more than the displayed size, the trader will have discovered the hidden liquidity, but only to the extent of his order size.

cancel their orders manually, or they may instruct their agents to cancel them at some prespecified time. The order cancellation strategy frustrates the quote-matching strategy by making it difficult to identify a trader's true intentions. It also makes the quote-matching strategy more risky by reducing the order option values: When traders cancel their orders frequently, quote-matchers cannot rely upon them to take them out of unprofitable positions.

The final method for controlling order exposure is to break orders into small pieces and distribute the pieces through time and/or across brokers. This strategy makes it difficult for quote-matchers to identify the full order before it executes. Traders who submit orders to completely confidential trading systems such as POSIT do not need to break up their orders. That traders routinely break up their large orders when trading at traditional exchanges suggests that they do indeed worry about how their size is treated on the floor.

C. Implications

Traders consider the advantages and disadvantages of order exposure when they decide how to trade. Exposure is generally advantageous if it does not create profitable front-running strategies. Time-precedence, in conjunction with an economically significant minimum price variation, helps protect exposed orders by making front-running strategies less profitable.

These arguments suggest several testable hypotheses:

- For a given tick, traders will expose small orders more than large orders.
- Order exposure in order-driven price-time precedence systems will increase with tick size.
- Traders will allow their orders to stand for longer, and they will cancel their orders less often, when the tick is large relative to price.
- The average trade size will be smaller when the relative tick is small.
- Order exposure will be smaller when volatility is higher (because order option values increase with volatility).

This study tests these implications using Paris Bourse and Toronto Stock Exchange data.

D. Relation to Previous Work

This study is related to several lines of research. Many previous studies examine the empirical relation between tick size, market liquidity, and trading volumes. Harris (1991, 1994), Bacidore (1996), Ahn, Cao and Choe (1996), Crack (1995), Ting and McInish (1995), Hameed and Terry (1995), and Niemeyer and Sandas (1993) respectively analyze data from the New York Stock Exchange, Toronto Stock Exchange, American Stock Exchange, American Stock Exchange, Stock Exchange of Singapore, Stock Exchange of Singapore, and the Stockholm Stock Exchange. These studies all examine market quotes. None examine orders as does this study. Their results generally show that quotation sizes and spreads increase with tick size.

Several studies examine theoretical issues related to those in this study. The first formal characterization of limit order option properties appears in Copeland and Galai (1983). Theoretical discussions of the importance of quote-matcher strategies designed to extract these option values first appear in Harris (1990) and Amihud and Mendelson (1991). Effects of the tick on liquidity supplied by dealers and limit order traders are examined in Chordia and Subrahmanyam (1995), Kandel and Marx (1995), Hollified, Miller and Sandås (1996), and Seppi (1995). Angel (1996) and Anshuman and Kalay (1994) consider whether firms split their stocks to adjust relative tick size and thereby increase liquidity. Regulatory issues involving tick size and time precedence are discussed in Harris (1993) and Hart (1993). Factors affecting the endogenous choice of a tick size are considered in Harris (1991) and Brown, Laux and Schachter (1991).

In some respects this paper is most closely related to two studies by Biais, Hillion and Spatt (1995, 1996). The first analyses how the flow of orders to the Paris Bourse varies by the state of the order book. It does not consider how the trading rules affect order exposure, however. The second paper examines order flow before the market opening call auction. The present study examines only trading in the continuous intraday session.

The title of McInish and Wood's (1995) paper, "Hidden Limit Orders on the NYSE," suggests a close relation to this work. Their study shows that specialists may fail to expose orders, but it does not consider why public traders may choose to not have them exposed. This study examines trader decisions to expose order flow.

II. Data

The data for this study come from the SBF Paris Bourse BDM database and from Toronto Stock Exchange order and trade files. The BDM database contains information about all stock orders, trades and quotes made at the Bourse. Since the CAC automated trading system produces these data, they are quite error-free.[6] The TSE data files provide similar information.

Some familiarity with the TSE and Bourse trading rules and procedures is necessary to understand the design of the empirical study and to interpret its results. This section describes these two markets, the stocks analyzed in the study, and the construction of the order sample.

A. Institutional Background

The Toronto Stock Exchange Computer Assisted Trading System (CATS) uses a pure price-time order precedence hierarchy to arrange trades. CATS allows large traders to partially display their orders. Traders who use this facility must display a minimum of 50 board lots, but they can specify more.[7] At a given price, undisclosed size has less precedence than disclosed size. When the exposed portion (and perhaps some of the hidden portion) of a partially disclosed order executes, the system then exposes more of the remaining undisclosed size. This process continues until the order is completely filled or the remainder is canceled.

Traders who use the TSE can see all displayed size on both sizes of the market, aggregated by price.[8] During the sample period analyzed in this study, the minimum price variation at the Toronto Stock Exchange was 1/8 dollar for all stocks trading above 5 dollars; 5 cents for prices between 3 dollars and 5 dollars, 1 cent between 50 cents and 3 dollars, and ½ cent below 50 cents. The minimum variations recently decreased slightly when the exchange converted to full decimal pricing on April 15, 1996.

The Paris Bourse Cotation Assistee en Continu (CAC) electronic trading system is very similar to (and is in fact derived from) the Toronto CATS system. Like CATS, CAC uses a pure price, exposure, time order precedence hierarchy. The exposed portions of partially displayed orders must be at least 10 times the minimum trading lot. Trading lots vary by stock.

---

[6] No reporting problems appear in the data such as those that often afflict manual trading systems. Some trader order submission errors appear, however. For example, some limit orders that cannot be executed upon submission (because their limit prices are inferior to the best opposing quote) have fill-or-kill instructions attached to them that immediately cancel them. Traders either mistakenly coded these orders, or they submitted them when the market was moving faster than they could react.

[7] A board lot varies by stock price. It is 100 shares for stocks trading above $1, 500 shares for stocks trading between $0.10 and $1, and 1000 shares for stocks trading under 10 cents. The TSE occasionally specifies special board lots for stocks that have changed price levels.

[8] The TSE also uses a second computer assisted trading system called the floor system, or CATS 2. TSE stocks trade either trade in CATS or in the floor system, but not in both systems. Unlike CATS, all orders in the floor system must be fully disclosed. The floor system also uses a slightly different time precedence rule. Floor system data are not used in this study.

Market orders submitted to the Paris Bourse are converted to limit orders upon submission to CAC. The limit price is set to price of the best opposing quote. The order is immediately matched at that price, first with the disclosed size, and then with any undisclosed size that may be present. If the liquidity offered at that price is insufficient to completely fill the order, the remainder of the order will stand at that price. Market order traders can submit disclosure instructions and fill-or-kill instructions that apply to the remainder.

The Paris Bourse maintains a block trading facility for its larger and more actively traded stocks. For these “block eligible” stocks, the Bourse computes a bid and ask for a standard block size from data in the displayed order book. The block bid and ask show the prices necessary to execute the standard block size, based only on displayed size. The block eligible stocks include all stocks in the CAC 40 Index and some other stocks with similar trading characteristics.

The minimum price variation at the Paris Bourse varies more with the price level than at the TSE. It is FF0.01 for stocks trading below FF5; 0.05 between 5 and 100; 0.10 between 100 and 500; 1 between 500 and 5000; and 10 above 5000.

B. The Sample Stocks

The Paris Bourse stock sample consists of all 300 French common stocks that traded in the continuous market on more than 25 days of the 41 trading days in the January and February 1995 sample period. This study analyzes only French common stocks to ensure that cross-sectional comparisons do not depend on security type or market of primary listing.[9]

The study examines only orders submitted between 10:00 AM and 5:00 PM while the market was open for continuous trading. The analysis excludes pre-opening orders because they are matched in an opening call auction. Traders who submit to the call auction may employ different order strategies than traders who submit to the continuous trading market.

The Toronto Stock Exchange sample consists of all 170 CATS-traded stocks for which traders submitted at least 50 intraday orders during the November 8, 9, 14-18, 1994 sample

[9] The Paris sample excludes eight continuously traded French stocks that did not trade more than 25 days in the sample period, and approximately 70 continuously foreign stocks. The primary markets for most of the foreign stocks are in their home countries, although some may trade primarily in Paris. Many more French stocks trade in the Bourse’s twice daily fixing (call) markets. These stocks are excluded because they are beyond the scope of this study.

period (seven trading days).[10] The TSE was open for continuous trading between 9:30 AM and 4:00 PM during the sample period.

C. Initial Sample Characterizations

Table I provides a summary characterization of the sample stocks. The Bourse stocks are larger and more actively traded then the TSE stocks. Equal-weighted average capitalization in the Bourse sample is 5.8 times larger than in the TSE sample (after adjusting for exchange rate differences). The ratio of value-weighted average capitalizations (3.3) is somewhat smaller. The TSE sample includes proportionally more very small stocks than does the Bourse sample. Within each sample, size also varies considerably. The largest stocks are three to four orders of magnitude larger than the smallest stocks. Since trading activity is highly correlated with firm size, variables that characterize activity show similar variation within and across samples. Bid/ask spreads are likewise inversely correlated with firm size, both within and across samples.

The average relative tick is about 12 times larger at the Toronto Stock Exchange than at the Paris Bourse. As a result, far more ticks separate the best bid and offer at the Bourse than at the TSE. The value-weighted average spread is 12.4 ticks at the Bourse but only 2.1 ticks at the TSE. The relatively small tick size at the Paris Bourse makes it is less costly to step in front of an order there than at the TSE. Accordingly, order exposure should concern traders at the Bourse more than at the TSE.

Figure 1 shows that price levels and tick sizes within both samples vary considerably. Variation in the relative tick is necessary to identify the effect of tick size on order display in the cross-sectional analyses presented below. The figure also shows that the values of the average relative tick size in the two samples hardly overlap. Only 38 TSE stocks have average relative tick sizes smaller than the maximum found in the Paris sample and only 5 Paris stocks have average relative tick sizes greater than the minimum found in the TSE sample. The points that lie along the 45 degree lines in this log-log scatter plot correspond to stocks that traded only on one tick throughout the sample period.

Table II presents the cross-sectional distribution of tick sizes that appear in the sample. A

[10] The TSE provided data for the ten trading days in November 7-18, 1994. The sample does not include data for November 7 because prior day data was required to reconstruct the limit order book. November 10 does not appear in the sample because of a clerical problem that could not be corrected. The next day, November 11, therefore had to be omitted as well.

total of 274 Bourse stocks and 158 TSE stocks traded on only one tick during their respective sample periods. Prices for the other 26 Bourse and 12 TSE stocks appeared in two adjacent price regions so that they traded on two ticks. Time-series analyses of these stocks appear in Section V. No sample stocks traded on more than two ticks.

D. The Order Display Instruction Subsample

This study primarily analyzes orders. Since the purpose is to identify how traders managed their order exposure, these analyses examine only those orders over which traders could specify meaningful display instructions. For convenience, this set of orders will be called the order display instruction subsample.

The order display instruction subsample excludes all market and marketable limit orders that traders should have expected to fully execute upon submission.[11] Traders do not need to control the display of these marketable orders because they do not expect them to stand.[12] The subsample also excludes standing limit orders that are smaller than the required minimum display size since the trader must fully display them. The order display instruction subsample does include marketable orders with expected standing remainders smaller than the minimum display size. Although these remainders are too small to be partially displayed, traders can (and often did) specify fill-or-kill instructions to prevent their disclosure.

This study determines whether traders expected an order to completely fill by comparing the order instructions to contemporaneous quote information. For the Paris database, this information includes only the best quote, and for the block eligible stocks, also the block quote. A marketable order is expected to completely fill if it is smaller than the displayed size offered to it. In addition, limit orders smaller than the standard block size with prices equal or better than the appropriate block quote are also expected to completely fill. If an order arrived when no

---

[11] A marketable limit order is an order priced so that at least part of it can be executed upon submission. A marketable buy (sell) limit order has a limit price at least as high (low) or higher (lower) than the best offer (bid). In contrast, a standing limit order is an order priced that it cannot immediately be matched with another order.

[12] Traders who wish to fully control their ex ante order exposure can do so by only taking liquidity (issuing marketable orders) and never offering it. It might therefore appear that useful information about order display behavior would be lost by excluding fully marketable orders. Note, however, that in pure order-driven exchanges, all trades must be initiated by a liquidity taker. Liquidity-taking orders that are not expected to leave standing remainders are excluded in this study because it is impossible to determine whether a trader took liquidity because he wanted to control the exposure of his order, or simply because he wanted to complete a trade at an attractive price. Such classifications might be possible with a data set that included trader identifying information. It might also be possible to make some inferences from order timing, but such an analysis is beyond the scope of this study.

quote information was available, it cannot be classified and therefore is excluded from the order display instruction subsample. This classification algorithm unfortunately is based on less information than was available to the Paris traders. They could see displayed size, by price, behind the best quote. This information is indirectly inferred only for the block eligible stocks. For the TSE stocks, the full order book can be quite accurately reconstructed using methods similar to those employed in Kavajecz (1996).[13] The TSE orders were therefore classified using the same information available to the Toronto traders. For both exchanges, the classification uses quotes that stood five seconds before their arrival at the exchange. The quote data are lagged to reflect the latest information that the trader would likely have seen before submitting the order.

The classification algorithm identifies only the worst case execution scenarios that traders could have expected. In practice, marketable orders often discover undisclosed size. Traders may therefore expect that their orders will execute more fully than is apparent from an analysis of disclosed size only. Such expectations may arise through long-term experience, or traders may generate them through current experimentation. Although such expectations undoubtedly affect order submission strategy, this study does not explore the formation of such expectations.

The Paris Bourse order sample includes 1,387,039 observations for the 300 sample stocks. These include 262,998 opening orders and orders submitted before the open, 490 orders that were submitted when no quotes were available, 321,852 orders that reasonably could be expected to fill completely upon submission, and 198,263 standing limit orders that were too small to specify partial display. Of the remaining orders, 46,797 orders were records of prearranged trades entered by brokers or of changed order instructions for which the time of the change is unfortunately not recorded. After excluding these orders, 556,639 orders remained in the order display instruction subsample.

The TSE order display instruction sample includes only 6,059 orders.[14] Fewer orders

---

[13] The reconstruction is not perfect, however, because although the data set includes order cancellation instructions, it does not include the time of cancellation. The cancellation times therefore needed to assumed. Cancellation times for partially orders were assumed to be the time of the last fill. Orders that never filled were mostly behind the market and were therefore ignored. The Paris order book cannot be reconstructed because no order cancellation instructions appear in the Bourse database.

[14] The TSE order sample includes 52,737 observations for the 170 sample stocks. These include 5,008 orders entered before sample period; 804 entered on the missing day November 10 that remained open on November 11; 5,847 orders entered before the 9:30 open; 103 untriggered stop orders; 2,853 odd lot orders; 1,664 put-through orders (prearranged crosses); 739 orders submitted when no quotes were available, 10,477 orders that reasonably could be expected to fill completely upon submission; and 19,183 standing limit orders that were too small to

appear because the sample time-period is shorter (7 versus 41 days), because fewer stocks are in the sample (170 versus 300), and because the Paris stocks are on average 5.8 times larger than the TSE stocks. The average numbers of orders per day per stock per billion French francs of capitalization are comparable across the two samples. This ratio is 6.2 for the Bourse stocks versus 4.0 for the TSE stocks. The relatively small size of the TSE sample makes it difficult to obtain high resolution results for this market.

III. Preliminary Characterizations

Table III characterizes order display in the order display instruction subsample. Traders in both markets often restricted order display, especially for orders with large expected remainders. Most notably, traders specified display restrictions far more often at the Paris Bourse than at the TSE where the tick size was much greater. When the remaining size is greater than FF500,000, 74 percent of the Paris orders are not fully disclosed. At the TSE, only 13 percent of equivalent sized orders are not fully displayed.

Not surprisingly, smaller remainders are more fully disclosed in both markets. Two reasons explain why this is so. First, the fixed minimum quantity that traders must display is a larger fraction of remaining size when the remainder is small. Second, traders are probably more willing to display small remainders because their exposure is not as risky to the trader as is the exposure of large remainders. To confirm that the first explanation does not account for the entire result, the analysis was repeated by dropping from the subsample all standing orders with remainders too small to hide, and by computing the fraction of the disclosable remainder (the remainder less the minimum disclosure size) that was displayed. The results (not presented) confirm that small remainders are more often displayed than large remainders.[15]

Panel B of Table III presents results cross-tabulated by relative tick size. As hypothesized, Paris Bourse traders more often restricted order display when the relative tick size was small than large. This relation is not apparent in the Toronto data, probably due to the large tick size and the small sample size.

---

specify partial display. After excluding these orders, 6,059 orders appear in the order display instruction subsample.

[15] The results obtained using this alternative method are not emphasized because dropping from the sample small remainders that cannot be partially displayed ignores the fact that they can be completely hidden by issuing a fill-or-kill instruction.

The remaining panels of Table III present results cross-tabulated by variables that traders control. Panel C shows that buy and sell order display tendencies are economically indistinguishable. Panels D and E present cross-tabulation results by order price placement aggressiveness. In Panel D, absolute price aggressiveness is measured by the percentage difference between the order price and the midpoint of the bid and offer quotes.[16] (Aggressiveness is measured as the negative of this quantity for sell orders.) In Panel E, relative price aggressiveness is measured by an index of the order price placement relative to the best bid and offer. The index is $1-2(A-P)/(A-B)$ where A, B and P are respectively the bid, ask and order prices. This index assigns a value of -1 to orders placed at the best bid and a value of 1 to orders placed at the best offer. (Aggressiveness is measured as the negative of this quantity for sell orders.) For both measures of aggressiveness, the order price for a market order is set equal to the best opposing quotation price, which is the price at which the remainder stands when converted to a limit order.

The Paris results show that the relative price measure of order placement aggressiveness explains more variation in order display than does the absolute measure. Traders least display orders that just slightly improve the market and or that very aggressively demand liquidity. They more often display when they place standing orders that substantially improve the market. Traders who just slightly improve the market probably do not display much because quote-matching strategies are most attractive when they are placed in front of precommitted traders who do not aggressively price their orders. Traders who substantially improve the market, but who are unwilling to issue marketable orders, are aggressively searching for someone to fill their orders. They presumably display to allow willing counterparts to easily see their orders. Traders who place very aggressive marketable orders are probably either well informed traders, very impatient traders, or both. They probably avoid displaying because they do not want to telegraph their intentions. Traders who place their orders behind the market do not display as much as those who match the market. The latter probably include many value-motivated traders who are only willing to trade if the price is right. Since their orders will likely stand longer than orders placed

[16] The midpoint employed is a weighted average of the bid and the offer. The size of the bid is used to weigh the offer price and the size of the offer is used to weigh the bid price. This formula, which appears in Lee, Mucklow and Ready (1993) provides a better estimate of value than the unweighted quotation midpoint. Similar results were obtained for the unweighted midpoint.

closer to the market, they may give up substantial option value when displaying their orders (if the orders are not too far from the market).[17] The Toronto results are similar, although less clear due to the small sample size.

Panel F presents results cross-classified by order validity instruction. By definition, 100 percent of the remaining size of the fill-or-kill orders is undisplayed. In the Paris sample, the day orders are next most hidden, followed by the until-date orders and finally by the good-till-canceled orders. The ordering of these results is consistent with the expected time to order cancellation. The fill-or-kill orders cancel immediately. The day orders cancel at day-end. The until-date orders cancel on the trader specified date. At the Paris Bourse, the good-till-cancel orders cancel on the last day of the current month for securities that settle on T+3 (cash market settlement) and on the next settlement day for securities that settle monthly. Since order option values increase with their expected validity (time to cancellation) these results suggest that traders attempt to limit their order option values.

Panel G presents results cross-classified by submission time-of-day. At the Paris Bourse, traders hide their orders slightly more during the first and last ten minutes of the trading session than within the session. Since these periods have the greatest intraday price volatility, these results again suggest that traders attempt to limit their order option values. The TSE results are inconclusive, probably because of the small sample size.

The final panel of Table III presents results cross-classified by whether the order was linked to another order in the database. Linkages occur when one order cancels another order or is itself canceled by another order. Such changes typically take place when traders adjust their order instructions. Linked orders are therefore orders that traders closely manage. Traders who do not wish to display their orders probably will choose to adjust them frequently. Moreover, traders who choose to display large orders can protect their order option values by adjusting order prices as the market moves to keep them out-of-the-money. In both markets, the results confirm that traders display less size for linked orders than for not linked orders.

A table (not presented) similar to Table III was also prepared to examine classified means of the fraction of remaining order size that is not disclosed. The qualitative results are almost

[17] The rank ordering of these results may not be completely reliable because are obtained by pooling orders across stocks that differ substantially.

identical to those described above for the fraction of display-restricted orders. For most well populated classification cells, the mean undisclosed remaining size, stated as a percent of the total remaining order size, is about eight-tenths of the corresponding percentage of display-restricted orders (presented in Table III).

IV. Cross-Sectional Analyses

This section presents the results of cross-sectional regression analyses designed to identify factors that affect order display and market liquidity. The presentation is divided into two subsections. The first subsection analyzes dependent variables that characterize order display. These variables are computed from the order display instruction subsample. The second subsection analyzes broad measures of market liquidity. These variables include averages of quotation sizes, bid/ask spreads, daily volumes, daily numbers of trades, daily numbers of quotes, and trade sizes. With one exception noted below, both sets of analyses use the same set of explanatory variables.

All models include the average relative tick as an explanatory variable. The hypotheses advanced in this study suggest that order display will be greater when the tick is large relative to price. A large tick also should be associated with larger trades since traders have less incentive to break up their orders. Its effects on other broader measures of liquidity, however, are not always obvious. The average relative tick is computed by taking the time-weighted average of the current tick divided by the current quotation midpoint.

All models also include a measure of intraday volatility. Order display should be greater for low volatility stocks because volatility increases order option values. Volatility should likewise affect the measures of market liquidity because volatility generally hurts liquidity suppliers. However, since volatility also attracts speculation, its effect on the measures of market activity is ambiguous. Volatility is measured by the root mean squared 30 minute intraday return.[18]

Finally, all models also include market capitalization as a regressor. This variable provides information about the scale of market activity. Log market value is used to shrink market values

[18] The intraday returns are computed from log price relatives using last observed prices. The root mean squared return is used instead of the sample standard deviation because the sample period is far too short to obtain reliable estimates of the expected intraday return, which in any event should be extremely close to zero.

across the stocks.

Notably missing from the list of independent variables are direct measures of market activity and liquidity such as average volumes, spreads, and trade and quote frequencies. Although it is easy to imagine that these variables should be included, this analysis omits them because they are invariably endogenous. Rather than deal with the simultaneous equations problems that their inclusion would create, the analyses instead estimate reduced forms based only on a few exogenous variables.[19] This strategy is more necessary than conservative: Few credible exogenous variables are available to identify simultaneous equations in empirical market microstructure analyses.

The cross-sectional regressions are all estimated using weighted least squares. The observations are weighted by the number of orders used to compute the dependent variables for each stock. This weighting scheme models error term heteroskedasticity. It also gives greatest weight to the large stocks. Given their importance in the market, this characteristic of the analysis probably should be viewed as an advantage rather than as a subject of concern.

A. Cross-Sectional Determinants of Order Display

Four dependent variables are used to characterize trader propensity to control their order display in the various stocks. Each is computed from the order display instruction subsample.

The first three variables provide simple characterizations of the subsample. They are 1) the logit transform of the fraction of orders with remainders that do not fully disclose remaining size, 2) the logit transform of the mean undisclosed remaining size expressed as a fraction of remaining order size, and 3) the logit transform of the mean fraction of linked orders. The regressions use logit transforms of the variables to stretch the [0,1] range of the variables to the full number line. This transformation yields better specified econometric models.[20] These dependent variables are computed for each stock from the entire order subsample, and also from only those orders that had expected remainders of greater than FF200,000. The size-restricted

---

[19] To some extent, even these variables are endogenous. Angel (1996), for example, claims that price level is endogenous in the long-run. Volatilties may be endogenous if they include transitory components cause by trading phenomena. Amihud and Mendelsohn (1986) results suggest that even market value is endogenous.

[20] The transformations cannot be done if the variable to be transformed has a value of zero or one. To avoid these problems, the transforms were taken of the Bayesian posterior means of the frequencies. The posterior means were computed using a uniform prior, which is very slightly informative. Untransformed models were also estimated with essentially the same results.

variables probably better represent order display propensities because they only weight those orders where display issues are most pressing.

The last dependent variable is derived from estimates of an econometric model designed to characterize trader decisions to expose their orders. This measure is designed to correct a potential problem that may affect the first three dependent variables: The three simple dependent variables will provide poor cross-sectional measures of the display propensities if average order size and order price placement vary in the cross-section. For example, a high order display restriction rate for a stock may indicate that traders are particularly concerned about order display in that stock. Alternatively, it may simply indicate that traders in that stock submit large orders or place them just slightly into the market. To address this problem, a display propensity index must be created that takes into account order size and price placement. This study constructs such an index using a discrete choice, maximum likelihood logit model: A logit model is first fit to all orders (across all stocks) in the order display instruction subsample. The "dependent" variable of the analysis is the indicator of whether the trader attached instructions to limit the order display. The independent variables are the log order size and the absolute order price aggressiveness variable. Quadratic terms and the cross-product are also included so that the model response function is a second order Taylor series expansion of the unknown true response function. Predicted logits are then computed from the estimated model for each order in the subsample. A second logit model is next estimated for each stock.[21] The only independent variable in this model is the predicted logit from the first model. Its slope coefficient is set equal to 1 and an intercept is estimated for each stock. The estimated intercept measures relative propensity to restrict order display, after accounting for order size and price placement.[22]

The results from the Paris Bourse sample (Table IV) strongly confirm the main thesis of

[21] The logit model cannot be estimated for those stocks that had no display restricted orders. For these stocks, the index was computed by subtracting the predicted mean logit produced by the first model from the logit of the posterior mean of the restricted display rate.

[22] The cross-sectional weighted average of the intercept should be asymptotically near zero when the weights are given by the number of orders for each stock. This property follows from the fact that the stock specific intercept represents the degree to which the intercept in the common logit model needs to be offset to best characterize the particular stock. These offsets must add up to zero on average. For those stocks where traders more frequently restrict order display (after taking to account the order size and placement), the intercept will be positive. For those stocks where traders restrict display less frequently, the intercept will be negative. Since the logit is a log odds ratio, differences in estimated stock intercepts represent relative differences in trader propensities to display orders rather than absolute differences.

this study. Traders restrict display more when the average relative tick is small. The results are overwhelmingly statistically significant. Not surprisingly, the strongest results come from the models in which the dependent variable is computed only from the larger orders, and from the logit display propensity model.[23]

The Paris results also show that greater volatility is associated with less order display. This evidence suggests that traders are aware of, and attempt to restrict, their order option values.

Finally, traders tend to display more size in larger stocks, and they adjust their orders less frequently in these stocks. These results are probably due to the fact that larger stocks tend to trade more actively. Since the average time that an order stands is probably shorter for large stocks, traders do not need to control their display as much. (Unfortunately, the Paris Bourse database does not permit a direct study of this conjecture because order submission and execution times are not linked.)

Since the relative tick is the primary variable of interest in this study, it is necessary to consider whether its statistical significance might simply be due to variation in the price that appears in its denominator. To address this question, the regression models were all reestimated with the inverse average price level added to independent variable list. The results for the logit index model appear at the bottom of Table IV. The inverse price variable is statistically insignificant and the estimate and the statistical significance of the relative tick coefficient are largely unchanged. Results (not presented) for the other dependent variables are similar.

The results (not shown) for the Toronto Stock Exchange sample are broadly consistent with the Paris results. They are weaker, however, because of the shorter time-series sample and because traders do not restrict order display as much in Toronto as in Paris (presumably because of the differences in tick size).

The regressions were also estimated from both stock samples pooled together. The results (not shown) are similar to the Paris results and statistically more significant. The increased significance is primarily due to the higher relative tick and the lower propensity to restrict display found in the Toronto sample as compared to the Paris sample.

---

[23] A pooled time-series cross-sectional model was also estimated with similar point results. The results are not presented because the statistical significance of the estimates is grossly over-stated when time-series dependencies within each stock are not modeled. It is extremely difficult to properly model such dependencies given the discrete model and the sample size.

B. Cross-Sectional Determinants of Various Liquidity Measures

This subsection presents estimation results for regression models designed to characterize how measures of market liquidity are related to the relative tick. The first measure examined is the log average French franc displayed quotation size.[24] This variable is computed as the time-weighted average of the bid and offer sizes. It should be positively related to the relative tick size if traders display more when the tick is large.

Quotation size by itself, however, can be a misleading measure of order display if comparisons are to be made across stocks with different average spreads. Traders may not offer much size at the market in stocks with narrow spreads whereas they may offer substantial size at the market for stocks with wide spreads. This relation is an expected consequence of adverse selection and does not necessarily indicate anything about trader concerns about front-running.[25]

A more reliable measure of quotation display size that addresses this problem is the ratio of the average quotation size to the relative bid/ask spread. This ratio estimates the rate at which displayed liquidity increases with quotation size. It is computed from the market quote for all stocks in the sample, and where possible, from the block quote for the Paris block eligible stocks.

The next measure examined is the relative bid/ask spread. It is computed as the time-weighted average of the ratio of the quotation spread to the quotation midpoint. The effect of the relative tick on the relative spread is not obvious. If the tick is relatively large, it may prevent dealers from quoting tight spreads for small sizes. Alternatively, a relatively small tick may so reduce the display of size that dealers may be unwilling to quote tight spreads. The first effect probably is the more important since traders often make a market for small size even when they cannot see large orders.

The next liquidity measure examined is the log average daily French franc trading volume. If a small tick increases transaction costs for large traders, trading volume should be small. This effect, if present, will be hard to identify because of the noise in volume and because it is a secondary prediction of the display thesis.

The final two liquidity measures examined are the log average daily number of trades and the log average trade size. These measures are important because they may reveal the extent to which traders break up their orders to avoid exposing them. If they do, the daily number of trades

[24] Size is measured in francs instead of shares to permit meaningful comparisons across the stocks.

should be negatively related to the relative tick size and the average trade size should be positively related to the relative tick size.

With one exception, these regressions use the same dependent variables as those reported above for the order exposure variables. The exception appears in the models for the average daily number of trades and the average trade size. These models also include the log French franc minimum lot size as an independent variable. If the minimum lot size is binding on many traders, it will affect these averages.

The Paris results (Table V) show that that relative tick is positively related, as expected, to the absolute and ratio measures of quotation size. The estimates are statistically significant. Volatility in these models also has the expected coefficient sign and is also statistically significant. Both effects suggest that traders consider and protect order option values. Not surprisingly, the log market value coefficient is positive and overwhelmingly significant. The addition of inverse price to these models does not affect these results.

The results from the average relative spread model appear exactly as expected for the volatility and firm size variables. Greater volatility is associated with larger spreads and greater size is associated with smaller spreads. The results for the relative tick size depend on whether the inverse price level appears in the model. A large tick appears to be associated with smaller spreads, but the relation is not statistically significant when inverse price appears in the model.

Not surprisingly, log market value is overwhelmingly statistically significant in the log average daily volume model and the log daily average number of trades model. The other variables are much less significant and their estimates behave inconsistently when inverse price is added to the regression.

Finally, estimates for the log average trade size model appear as expected, although they are a bit weak for the relative tick size variable. A large tick is associated with larger trades, as is a large minimum lot size. Greater volatility is associated with smaller trades, possibly because traders are afraid to expose significant size in volatile markets.

Although the inverse price level is statistically significant in many of these regressions, its significance may have more to do with the sample than with any omitted variables. An examination of the average prices reveals why it may be statistically significant. The Paris sample

[25] Easley and O'Hara (1987) provide a model that explains why this may be.

includes a very small number of stocks with prices that are very low compared to the prices of most stocks in the sample. The inverse price level is large for these stocks and near zero for the rest of the sample. The inverse price level therefore acts somewhat like a dummy variable for this small subset of stocks. While this subset of stocks may indeed trade in ways fundamentally different from the rest of the sample, dummy variables invariably will be statistically significant when they identify a small subsample of a much larger sample. It therefore is not obvious that the statistical significance of the inverse price variable is meaningful, especially without any reasonable model of why it should be so.

The Toronto results (not reported) are again essentially similar to the Paris results, but much weaker. The tick size coefficient estimates in the absolute and relative quotation size models are both positive and strongly significant. In the other models, these estimates are all positive, but statistically insignificant.

V. Time-Series Analysis

As noted above in Section C, 26 of the 300 Paris stocks and 12 of the 170 TSE stocks traded in two tick size regimes within the sample period.[26] This section compares their market activity under the two regimes. Although there are few such stocks, the analysis is potentially quite strong: By comparing activity across regimes for the same stock, omitted variable effects presumably will be quite small.

To compare the regimes, two values for each dependent variable analyzed in the preceding section are separately computed. The first value is computed only from those periods when the stock traded on its smaller tick; the second value is computed only from periods when the stock traded on its larger tick. Paired *t*-tests are then used to compare the values of these variables under the different regimes. Although the levels and relative sizes of the transitions vary, the data for all stocks are pooled together to maximize the power of the tests.

The total time during which these stocks traded on one tick versus another varies considerably within the sample. For example, two Paris stocks changed regimes, returned on the same day, and then did not change again. The vast majority of the trades and orders for these two

[26] For some stocks, a single transition from one tick size to another took place as the stock price rose or fell during the sample period. For other stocks, the transition took place multiple times as the stock price repeatedly rose and fell across the transition price. No changes in tick levels in this sample took place because of splits.

stocks therefore are associated with only one tick. The other stocks dwelled for varying amounts of time in their two tick size regimes. The analysis variable means therefore are estimated with varying degrees of error.

To model heteroskedasticity in the differences in the paired means, weighted paired *t*-tests are conducted. Each difference in paired means is weighted by a factor proportional to the variance of the difference. The weighting formula assumes that all observations are drawn from a constant variance distribution.[27] This weighting scheme gives the greatest weight to stocks with many observations under both regimes and least weight to stocks with only a few observations in one regime, regardless of how many observations are in the other regime.

Table VI presents the small and large tick cross-sectional mean values for the order display variables, and the associated paired *t*-tests. The means are weighed by the same weights used to compute the *t*-tests so that they are comparable. The Paris results show that traders exposed less, and adjusted their orders less frequently, when the tick was small than when it was large. The differences are all statistically significant. Not surprisingly, the results are stronger for the order display measures that are computed from only larger orders than from all orders. The strongest statistical results are obtained from the logit index measure, which adjusts for order size and price placement. The Toronto traders also exposed less when the tick was smaller but they adjusted their orders slightly more often. The exposure results are statistically significant but the adjustment results are not.

Table VII presents cross-sectional mean values for several variables that measure liquidity characteristics and other variables of interest in the Paris tick-change sample. Since the mean variable values vary substantially in the cross-section, the *t*-statistics presented in this table test for the paired differences in the logged means rather than for differences in the actual means. This change reduces the heteroskedasticity of the differences. The resulting test therefore examines percentage differences rather than actual differences. In all other respects, the methods are the same as those used in the previous table. The first line shows that the average price did not vary much between the two regimes. The average percentage difference between the two mean prices is only 7.6 percent. Although the associated *t*-statistic appears to be significant, it is meaningless because the tick regimes depend on the price levels.

The next two lines show that the quote size was substantially bigger for the large tick than for the small tick. The result holds both for size measured in shares and for size measured in French francs. The share results are important because they show that the French franc results are not merely due to the higher stock price associated with the larger tick size. The differences are significant.

The next two lines show that the ratio of quoted size to the bid/ask spread was higher for the large tick than for the small tick. The difference is large and statistically significant for the market quotes. It is large but statistically insignificant for the block quote ratios, for which only four stock observations appear in the sample. These results are consistent with the thesis of this study: Traders appear to offer more liquidity when protected by a large tick.

The next three lines show how spreads varied between the two regimes. The average spread was wider both in relative terms and in absolute terms when the stocks traded on the larger tick. The mean percentage differences are both statistically significant. Not surprisingly, the spread measured in ticks is much smaller for the larger tick. It appears that the smaller ticks allow dealers to quote tighter spreads, albeit for smaller sizes.

The remaining variables that appear in the table – trade size in French francs and in shares, daily number of trades, and daily volume in French francs and in shares – all have statistically insignificant percentage differences. French franc trader size is probably the most important of these variables since it indicates the extent to which large traders break up their trades. It is larger for larger tick sizes, as expected, but the *t*-statistic is only 1.2. The lack of significance is probably due to noise in these variables and to the fact that the expected effects on these variables are all only secondary predictions of the order display argument.

Results (not shown) for a similar analysis of the Toronto tick-change sample are uniformly uninformative. The sample apparently is too small to produce meaningful results.

VI. Conclusion

A. Summary

This study examines cross-sectional and time-series evidence to identify factors that traders consider when displaying their orders. The evidence strongly suggests that traders expose

---

[27] The weights are given by $1 \big/ \left(1/N_L + 1/N_S \right)$.

more when the minimum tick is large, when the order is not expected to stand long, and when prices are not volatile. These results suggest that traders recognize and attempt to control the option values associated with their orders.

The results demonstrate that the minimum price variation has important effects on order exposure. The current regulatory initiatives to lower tick sizes therefore may be misguided if order exposure is desirable. Also, attempts to compel traders to display their orders may decrease market liquidity.

B. Directions for Future Research

The effects of tick size on measures of market liquidity like volumes and spreads are harder to measure than are the effects on order exposure. Larger samples will need to be examined to identify a relation, if any, among these variables.

This study examines only unconditional measures of order exposure. Traders undoubtedly condition their order exposure decisions on current market conditions such as the width and depth of the market quote. An analysis of how traders condition their decisions would greatly broaden our understanding of order exposure.

It should be possible to directly identify the activities of quote-matching traders. A characterization of this behavior would broaden our understanding of the environment risks that traders face when offering liquidity.

References

Ahn, Hee-Joon, Charles Cao and Hyuk Choe, 1996, "Tick Size, Spread and Volume" *Journal of Financial Intermediation*, 5.

Amihud, Y. and H. Mendelson, 1986, "Asset Pricing and Bid-Ask Spread," *Journal of Financial Economics*, 17, 223-249.

Amihud, Yakov, and Haim Mendelson, 1990, "Option Market Integration: An Evaluation," Paper submitted to the US Securities and Exchange Commission.

Angel, James, 1996, "Tick Size, Share Prices, and Stock Splits," forthcoming *Journal of Finance*.

Anshuman, V. R. and A. Kalay, 1994, "Can Splits Create Market Liquidity? Theory and Evidence," working paper, University of Utah.

Bacidore, Jeffrey M., 1996, "The Impact of Decimalization on Market Quality: An Empirical Investigation of the Toronto Stock Exchange," Indiana University Working Paper

Biais, B., P. Hillion and C. Spatt, 1995, "An Empirical Analysis of the Limit Order Book and the Order Flow in the Paris Bourse," *Journal of Finance*, 50, 1655-1689.

Bruno Biais, Pierre Hillion and Chester Spatt, 1996, "The Formation of the Opening Price in the Paris Bourse: An Empirical Study of Walrasian Tatonnement and Preplay Communication," working paper, Carnegie-Mellon University.

Brown, Sharon, Paul Laux and Barry Schachter, 1991, "On the Existence of an Optimal Tick Size," *Review of Futures Markets*, 10, 50-72.

Chordia, Tarun and Avanidhar Subrahmanyam, 1995, "Market Making, the Tick Size, and Payment-for-Order Flow: Theory and Evidence" *Journal Of Business*, 68, 543-75.

Copeland, Thomas E. and Dan Galai, 1983, "Information Effects on the Bid-Ask Spread," *Journal of Finance*, 38, 1457-69.

Crack, Timothy, 1995, "Tinkering with Ticks: Choosing Minimum Price Variation for US Equity Markets," working paper, working paper, MIT.

Easley, D. and M. O'Hara, 1987, "Price, Trade Size and Information in Securities Markets," *Journal of Financial Economics*, 19, 69-90.

Glosten, L. and L. E. Harris, 1988, "Estimating the Components of the Bid-Ask Spread," *Journal of Financial Economics*, 21, 123-142.

Hameed, Allaudeen and Eric Terry, 1995, “The Effect of Tick Size on Price Clustering and Trading Volume,” working paper, National University of Singapore.

Harris, L. E., 1990, “Liquidity, Trading Rules, and Electronic Trading Systems,” *New York University Salomon Center Monograph Series in Finance*, Monograph 1990-4.

Harris, L. E., 1991, “Stock Price Clustering and Discreteness,” *Review of Financial Studies*, 4, 389-415.

Harris, Lawrence, 1993 “Consolidation, Fragmentation, Segmentation and Regulation,” *Financial Markets, Institutions & Instruments*, 2 (5), 1-28.

Harris, Lawrence, 1994, “Minimum Price Variations, Discrete Bid/Ask Spreads and Quotation Sizes,” *Review of Financial Studies*, 7, 149-178.

Hart, Michael A., 1993, “Decimal Stock Pricing: Dragging the Securities Industry into the Twenty-First Century” *Loyola of Los Angeles Law Review*, 26, 883-880.

Hollified, Burton, Robert A. Miller and Patrick Sandås, 1996, “An Empirical Analysis of An Electronic Limit Order Book,” working paper, University of British Columbia.

Kandel, Eugene and Leslie Marx, 1995, “NASDAQ Market Structure and Spreads Patterns,” working paper, William E. Simon Graduate School of Business Administration, University of Rochester.

Kavajecz, Kenneth A., 1996, “A Specialist’s Quoted Depth and the Limit Order Book,” working paper, Northwestern University.

Kyle, A. S., 1985, “Continuous Trading and Insider Trading,” *Econometrica*, 53, 1315-1335.

Lau, Sie Ting and Thomas McInish, 1995, “Reducing Tick Size on the Stock Exchange of Singapore,” working paper, Memphis State University.

Lee, C. M. C., B. Mucklow and M. J. Ready, 1993, “Spreads, Depths and the Impact of Earnings Information: An Intraday Analysis,” *Review of Financial Studies*, 6, 345-374.

McInish, Thomas H and Robert A. Wood, 1995, “Limit Order Display on the NYSE,” *Journal of Portfolio Management*, (Spring) 19-26.

Niemeyer, Jonas and Patrik Sandas, 1993, “Tick Size, Market Liquidity and Trading Volume: Evidence from the Stockholm Stock Exchange,” working paper, Stockholm School of Economics.

Securities and Exchange Commission, Division of Market Regulation, 1994, *Market 2000: An Examination of Current Equity Market Developments*, U.S. Government Printing Office.

Seppi, Duane J., 1995, "Liquidity Provision with Limit Orders and a Strategic Specialist," Working paper, Carnegie Mellon University.

Wallman, Steven M. H., 1996, "Technology and Our Markets: Time to Decimalize," Speech given before the Pace University Center for the Study of Equity Markets.

Table I

Characteristics of the Cross-Sectional Stock Samples

The Paris sample consists of all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The TSE sample consists of all 170 common stocks that traded in the Toronto CATS system for which traders submitted at least 50 orders during the November 8, 9, 14-18, 1994 sample period. Common stock capitalization is as of December 31, 1994 for the Paris stocks and as of August 31, 1994 for the TSE stocks. For the TSE stocks, the daily root mean squared return is calculated for the period January 1, 1994 -- October 31, 1994. All other statistics are computed over the sample period. A Canadian dollar was worth approximately 3.8 French francs at the end of 1994.

Variable	Market	Equal-Weighted Mean	Value-Weighted Mean	Minimum	Maximum
Common Stock Capitalization	Paris	7293	32768	16	98584
(Millions of FF and CAN$)	TSE	331	2585	1	9585
Daily Root Mean Square Return	Paris	1.58	1.50	0.44	13.18
(Percentage)	TSE	3.32	1.96	0.78	19.10
Average Daily Trading Volume	Paris	8.06	43.70	0.01	138.16
(Millions of FF, CAN$)	TSE	0.17	0.53	0.004	3.33
Average Trade Price	Paris	607	632	8	6450
(FF, CAN$)	TSE	8	17	0.1	47
Average Tick Size	Paris	0.50	0.543	0.05	10.00
(FF, Cents)	TSE	7.8	11.8	0.5	12.5
Average Tick Size	Paris	7.9	7.7	2.1	58.7
(Percentage Basis Points of Price)	TSE	115.3	88.8	26.3	361.1
Number of Sample Days with	Paris	40	41	26	41
Trades	TSE	6.6	6.9	3	7
Average Daily Number of	Paris	87	382	2	1378
Continuous Session Orders	TSE	31	47	7	395
Average Daily Number of	Paris	74	336	1	1000
Continuous Session Trades	TSE	17	28.3	1.5	256
Average Spread	Paris	9.0	4.1	0.1	136.1
(FF, Cents)	TSE	18.8	22.5	0.7	170.5
Average Spread	Paris	1.24	0.53	0.13	4.84
(Percentage of Price)	TSE	2.88	1.46	0.61	11.79
Average Spread	Paris	34.9	12.4	1.3	190.7
(Number of Ticks)	TSE	3.8	2.1	1.0	35.3

(Continued)

Variable	Market	Equal-Weighted Mean	Value-Weighted Mean	Minimum	Maximum
Average Bid Size	Paris	94	242	4	836
(Thousands of FF and CAN$)	TSE	33	100	1	343
Average Ask Size	Paris	105	248	6	745
(Thousands of FF and CAN$)	TSE	43	111	1	794
Average Trade Size	Paris	64.5	116	0.8	233
(Thousands of FF and CAN$)	TSE	9	18	0.9	67

Table II

Cross-Sectional Frequency Distribution of Tick Sizes that Appear in the Samples and Associated Cross-Sectional Average Prices and Relative Tick Sizes

The Paris sample consists of all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The Toronto Stock Exchange sample consists of all 170 common stocks that traded in the Toronto CATS system for which traders submitted at least 50 orders during the November 8, 9, 14-18, 1994 sample period. No sample stock traded on more than two ticks.

Paris Bourse					Toronto Stock Exchange				
		Number of Tick Sizes Used					Number of Tick Sizes Used		
Price	Tick	1 only	2 Sizes		Price	Tick	1 only	2 Sizes	
Region (FF)	Size (FF)	Unique Tick	Smaller Tick	Larger Tick	Region (Cents)	Size (cents)	Unique Tick	Smaller Tick	Larger Tick
Panel A: Number of Stocks									
5-100	0.05	17	6		0-0.50	0.5	8	3	
100-500	0.10	156	19	6	0.50-3	1	43	4	3
500-5000	1	99	1	19	3-5	5	15	5	4
>5000	10	2		1	>5	12.5	92		5
All	All	274	26	26	All	All	158	12	12
Panel B: Average Trade Price (FF, CAD$)									
5-100	0.05	50	94		0-0.50	0.5	0.3	0.5	
100-500	0.10	295	469	106	0.50-3	1	1.5	2.7	0.6
500-5000	1	1103	4801	523	3-5	5	4.1	4.7	3.2
>5000	10	5929		5310	>5	12.5	13.8		5.3
All	All	611	549	608	All	All	8.9	2.9	3.7
Panel C: Average Tick (Percentage Basis Points of Price)									
5-100	0.05	17.4	5.3		0-0.50	0.5	207	104	
100-500	0.10	4.0	2.2	9.4	0.50-3	1	82	37	180
500-5000	1	11.6	2.1	19.1	3-5	5	122	107	157
>5000	10	17.0		18.5	>5	12.5	116		232
All	All	7.6	2.9	16.9	All	All	112	76	192

Table III

Restricted Order Display Frequency Distributions

This table presents statistics that characterize all orders that could not be fully executed upon submission and which are large enough that the trader could specify a meaningful disclosure instruction. The Paris sample includes all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The Toronto Stock Exchange sample includes in all 170 common stocks that traded in the CATS system for which traders submitted at least 50 orders during the November 8, 9, 14-18, 1994 sample period. Remaining size is the portion of the order that cannot be expected to fully execute with certainty upon submission. Undisclosed remaining size arises when the trader instructs that it not be disclosed, or when the trader issues a fill-or-kill instruction. A linked order either adjusted another order or was canceled by another order. Percentages greater than zero but less than 0.5 are indicated by "+0."

	Orders with Some Undisclosed Remaining Size (Percent)					Number of Orders Per Cell				
Remaining Order Size (1,000 FF)	0-10	10-50	50-200	200-500	>500	0-10	10-50	50-200	200-500	>500
Panel A: Full Sample										
Paris	5	9	19	37	74	20792	66394	168905	164844	135704
Toronto	1	1	3	4	13	899	2039	2067	736	318
Panel B: Cross-Classified by Relative Tick Size (in basis points)										
Tick Size						Paris Bourse				
2-5	6	8	18	42	79	11044	37628	106872	95718	71666
5-10	4	11	27	42	74	6944	15875	30726	25991	24994
10-20	9	10	16	24	65	2027	9939	29161	42217	38267
20-50	7	9	8	22	50	576	2230	2016	892	769
50-100	3	4	30	38	38	182	720	128	26	8
>100	5	100	+0	n/a	n/a	19	2	2	0	0
						Toronto Stock Exchange				
2-5	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0
5-10	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0
10-20	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0
20-50	+0	+0	5	3	3	155	344	387	73	36
50-100	1	1	5	2	8	263	652	464	160	182
>100	1	1	1	4	25	481	1043	1216	503	100

(Continued)

Panel C: Cross-Classified by Side

Remaining Order Size (1,000 FF)	Orders with Some Undisclosed Remaining Size (Percent) 0-10	10-50	50-200	200-500	>500	Number of Orders Per Cell 0-10	10-50	50-200	200-500	>500
Side						Paris Bourse				
Buy	7	9	19	38	74	8592	32685	84573	83349	67016
Sell	4	9	19	36	74	12200	33709	84332	81495	68688
						Toronto Stock Exchange				
Buy	1	1	2	4	12	485	1013	1029	324	134
Sell	+0	1	4	3	14	414	1026	1038	412	184

Panel D: Cross-classified by order price aggressiveness, as measured by the signed distance between order price and the quotation mid-point ($P/M-1$ for buy orders; $1-P/M$ for sell orders)

Aggressiveness						Paris Bourse				
Low- -2%	1	4	23	44	71	5164	12915	9761	6309	5861
-2 - -1%	1	7	26	46	75	2184	6701	11788	10825	9573
-1 - -0.5%	+0	6	20	42	75	1689	6611	18982	19865	17380
-0.5 - -0.2%	1	4	15	37	75	1340	7231	32886	35859	30126
-0.2 - 0.2%	10	11	17	32	73	6047	23634	82906	84176	65683
0.2 - 0.5%	15	19	36	58	81	1791	4593	7698	5220	4914
0.5 - 1%	11	18	38	64	78	1073	2448	2967	1689	1396
1 - 2%	7	13	38	61	68	752	1310	1249	668	477
2 - High	3	10	26	49	52	752	951	668	233	294
						Toronto Stock Exchange				
Low- -2%	1	2	4	3	23	136	401	387	124	30
-2 - -1%	5	2	1	7	15	37	185	227	104	47
-1 - -0.5%	+0	2	5	3	8	25	124	203	70	49
-0.5 - -0.2%	+0	1	4	3	10	15	68	149	60	50
-0.2 - 0.2%	+0	+0	2	4	7	180	420	385	162	75
0.2 - 0.5%	1	+0	2	1	16	148	279	255	68	32
0.5 - 1%	+0	+0	2	1	26	137	254	251	93	19
1 - 2%	+0	1	1	5	15	117	171	139	38	13
2 - High	+0	+0	1	6	33	104	137	71	17	3

(Continued)

Panel E: Cross-Classified by Order Price Aggressiveness, as Measured by the Relation Between Order Price and the Best Bid and Ask Quotes

Remaining Order Size (1,000 FF)	Orders with Some Undisclosed Remaining Size (Percent) 0-10	10-50	50-200	200-500	>500	Number of Orders Per Cell 0-10	10-50	50-200	200-500	>500
(Ask=1, Bid=-1 for Buy Orders; Bid=1, Ask=-1 for Sell Orders)										
Aggressiveness						Paris Bourse				
P < -1	+0	3	15	34	71	9527	26352	54815	61052	55338
P = -1	1	5	14	31	73	898	5434	26106	31322	24991
-1< P < -1/3	3	9	19	45	84	1122	9767	38860	30922	20357
-1/3<P < 1/3	1	4	10	22	68	660	3023	10452	13258	9435
1/3< P < 1	2	4	10	28	62	261	701	1051	716	625
P = 1	16	22	35	49	77	5198	14294	26565	19381	16329
P > 1	5	10	26	49	77	3126	6823	11056	8193	8629
						Toronto Stock Exchange				
P < -1	4	2	4	5	19	84	292	388	123	57
P = -1	2	1	3	3	9	66	220	417	205	124
-1< P < -1/3	+0	2	7	4	33	57	191	148	25	3
-1/3<P < 1/3	+0	2	2	7	19	45	210	262	124	57
1/3< P < 1	+0	+0	2	+0	n/a	115	166	98	15	0
P = 1	+0	+0	2	2	9	507	922	730	238	75
P > 1	+0	+0	+0	+0	+0	25	38	24	6	2

Panel F: Cross-Classified by Order Validity Instruction

Validity						Paris Bourse				
Fill or Kill	100	100	100	100	100	1009	3704	10684	10777	13587
Day order	1	6	14	33	71	6699	37055	144777	147719	119269
Until date	+0	+0	6	23	62	1123	3230	1046	469	407
G-T-C	+0	1	7	17	52	11961	22405	12398	5879	2441
						Toronto Stock Exchange				
Fill or Kill	100	100	100	100	n/a	1	2	2	1	0
Day order	+0	1	2	4	10	749	1695	1699	589	262
Until date	3	2	5	5	31	120	235	226	44	13
G-T-C	+0	+0	1	2	28	29	107	140	102	43

(Continued)

Panel G: Cross-Classified By Order Submission Time

Time	Paris Bourse

Remaining Order Size (1,000 FF)	Orders with Some Undisclosed Remaining Size (Percent) 0-10	10-50	50-200	200-500	>500	Number of Orders Per Cell 0-10	10-50	50-200	200-500	>500
First 10 minutes	7	11	23	40	77	1050	3555	8246	8041	6559
9:10-13:30	5	8	20	40	76	11042	33888	75976	70475	55907
13:30-16:50	6	9	18	34	71	8099	26705	77066	77585	64002
Last 10 minutes	6	12	22	39	75	601	2246	7617	8743	9236
					Toronto Stock Exchange					
First 10 minutes	+0	1	2	+0	11	35	112	129	53	18
9:40-13:30	1	1	3	4	14	537	1278	1277	436	208
13:30-16:50	1	1	3	3	7	286	574	583	216	82
Last 10 minutes	+0	+0	+0	6	30	41	75	78	31	10

Panel H: Cross-Classified by Whether the Order was Linked to Another Order

Status					Paris Bourse					
Linked	5	10	19	41	80	1556	15024	78169	81298	68727
Not Linked	5	9	19	34	68	19236	51370	90736	83546	66977
					Toronto Stock Exchange					
Linked	+0	1	3	6	24	180	517	540	210	93
Not Linked	1	1	2	2	8	719	1522	1527	526	225

Table IV

Cross-Sectional Regressions of Order Disclosure Indicators

This table presents weighted least squares cross-sectional regression estimates. The dependent variables are various statistics that characterize order disclosure for each stock. They are computed from all orders that could not be fully executed upon submission and which are large enough that the trader could specify a disclosure instruction. The observations are weighted by the number of orders used to compute the dependent variables for each stock. Remaining size is the portion of the order that cannot be fully executed with certainty upon submission. A linked order either adjusted another order or was canceled by another order. The logistic model intercept measures the relative propensity of traders to attach disclosure instructions to their orders, after taking into account order size and price placement. The relative tick is the average of the minimum price variation divided by price. Volatility is measured by the root mean squared 30 minute intraday transaction return. The sample consists of all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. Estimate *t*-statistics are in parenthesis.

Dependent Variable Order Sample	Intercept	Relative Tick	Volatility	Log Market Value	Inverse Price	R^2	N
Logit transform of the fraction of orders that do not fully disclose remaining size							
All orders	-0.10	-3.13	0.38	-0.13		26.7	300
	(-0.60)	(-7.9)	(1.65)	(-4.50)			
Orders > FF200,000	1.33	-5.98	1.16	-0.34		60.7	298
	(6.4)	(-12)	(4.20)	(-10.0)			
Logit transform of the mean undisclosed remaining size expressed as a fraction of remaining order size							
All orders	-0.58	-3.11	0.39	-0.10		31.1	300
	(-4.09)	(-9.4)	(2.08)	(-4.35)			
Orders > FF200,000	0.59	-5.05	1.01	-0.28		62.4	298
	(3.48)	(-13)	(4.49)	(-10)			
Logit transform of the mean fraction of linked orders							
All orders	-0.13	-2.39	0.13	0.03		21.2	300
	(-1.09)	(-8.6)	(0.79)	(1.43)			
Orders > FF200,000	-0.08	-2.67	0.53	0.04		30.4	298
	(-0.73)	(-11)	(3.83)	(2.61)			
Logistic model intercept measure of hidden order usage							
All orders	0.81	-5.38	1.41	-0.35		73.7	300
	(4.91)	(-14)	(6.5)	(-13)			
All orders	0.88	-5.85	1.31	-0.36	5.02	73.9	300
	(5.2)	(-12)	(5.8)	(-14)	(1.59)		

Table V

Cross-Sectional Regressions of Stock Liquidity Indicators

This table presents weighted least squares cross-sectional regression estimates. The dependent variables are various statistics that characterize liquidity for each stock. They are computed from order and transaction time-series. The observations are weighted by the number of quotes, trades, or days used to compute the dependent variables for each stock. The relative tick is the average of the minimum price variation divided by price. Volatility is measured by the root mean squared 30 minute intraday transaction return. The sample consists of all 300 French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The regression involving block statistics has only 52 observations because only 52 stocks are block eligible. Estimate *t*-statistics are in parenthesis.

Intercept	Relative Tick	Volatility	Log Market Value	Inverse Price	Log Min Display Size	R^2	N
Log Average Inside Quote Size (Thousand FF)							
4.56	4.72	-1.51	0.33			81.2	300
(35)	(18)	(-8.6)	(16)				
4.23	6.37	-1.09	0.36	-15.18		84.1	300
(33)	(19)	(-6.4)	(18)	(-7.4)			
Log Ratio of Average Inside Quote Size to Average Relative Spread (Thousand FF/Percent)							
5.16	4.95	-2.90	0.69			89.8	300
(29)	(14)	(-12)	(24)				
5.04	5.59	-2.74	0.70	-5.89		89.9	300
(27)	(11)	(-11)	(24)	(-1.96)			
Log Ratio of Block Quote Size to Average Block Relative Spread (Thousand FF/Percent)							
14.48	3.80	-5.09	0.51			91.2	52
(40)	(8.0)	(-11)	(8.2)				
14.59	3.51	-5.26	0.49	2.83		91.1	52
(37)	(5.7)	(-9.9)	(7.8)	(0.73)			
Average Relative Spread (Percent of Price)							
0.71	-0.65	0.91	-0.21			71.9	300
(7.1)	(-3.19)	(6.8)	(-13)				
0.61	-0.15	1.04	-0.20	-4.52		72.5	300
(5.9)	(-0.56)	(7.4)	(-12)	(-2.70)			

(Continued)

Intercept	Relative Tick	Volatility	Log Market Value	Inverse Price	Log Min Display Size	R^2	N
			Log Average Daily Volume (Million FF)				
0.86	2.77	0.25	1.15		0.18	73.5	300
(2.06)	(2.68)	(0.68)	(22)		(4.10)		
0.93	0.11	-0.16	1.15	28.36	0.22	74.3	300
(2.27)	(0.08)	(-0.43)	(22)	(3.19)	(4.79)		
			Log Average Daily Number of Trades				
-5.59	2.48	0.99	0.86		0.02	64.4	300
(-16)	(2.94)	(3.26)	(20)		(0.68)		
-5.48	-1.67	0.34	0.86	44.14	0.08	68.6	300
(-17)	(-1.62)	(1.13)	(21)	(6.4)	(2.18)		
			Log Average Trade Size (Thousand FF)				
3.61	0.07	-1.41	0.17		0.13	59.8	300
(18)	(0.22)	(-6.6)	(6.4)		(8.3)		
3.61	1.49	-1.13	0.19	-10.43	0.10	61.5	300
(18)	(3.06)	(-5.0)	(7.1)	(-3.69)	(5.7)		

Table VI

Mean Order Disclosure Characteristics, Classified by Tick Size, for Stocks that Traded on Two Different Tick Sizes During the Sample Period

This table presents cross-sectional means of various statistics that characterize order disclosure for each stock. The statistics are computed from all orders that could not be fully executed upon submission and which are large enough that the trader could specify a disclosure instruction. The paired *t*-statistics are for testing whether the differences in the paired means are zero. They are computed by weighting each difference by a constant proportional to the expected variance of the difference. The cross-sectional means are computed using the same weights. Remaining size is the portion of the order that cannot be fully executed with certainty upon submission. A linked order either adjusted another order or was canceled by another order. The logistic model intercept measures the relative propensity of traders to attach disclosure instructions to their orders, after taking into account order size and price placement. The samples consist of the 26 Paris stocks and the 12 Toronto stocks that traded on two different ticks during their respective sample periods. The Paris subsample of orders larger than FF200,000 includes orders from only 23 stocks because three stocks had no qualifying orders. No results are reported for the Toronto logistic model analysis because traders did not specify any order disclosure restrictions for seven of the 12 stocks.

	Tick Size		
Variable and Order Subsample	Smaller Tick	Larger Tick	Paired *t*-statistic
Mean percentage of orders with some undisclosed remaining size			
All Paris orders	42.6	37.1	-3.5
Only Paris orders larger than FF200,000	62.3	53.4	-5.0
All Toronto orders	3.4	1.4	-2.2
Mean undisclosed remaining size as a percentage of remaining order size			
All Paris orders	32.6	29.0	-2.6
Only Paris orders larger than FF200,000	49.0	41.7	-4.7
All Toronto orders	2.1	1.1	-1.7
Mean percentage of linked orders			
All Paris orders	49.6	38.8	-4.7
Only Paris orders larger than FF200,000	55.8	44.8	-4.9
All Toronto orders	25.8	29.7	1.0
Logistic model intercept measure of hidden order usage			
All Paris orders	0.61	0.20	-6.3

Table VII

Mean Liquidity Characteristics, Classified by Tick Size, for Stocks that Traded on Two Different Tick Sizes During the Sample Period

This table presents cross-sectional means of various statistics that were computed for each stock from order and trade time-series. The subsample consists of the 26 stocks from the main sample that traded on two different ticks during the sample period. The main sample consists of all French common stocks that traded in the Paris Bourse continuous market on more than 25 days of the 41 trading days in January and February 1995. The paired *t*-statistics are for testing whether the percentage differences in the means are zero. They are computed by weighting each difference by a constant proportional to the expected variance of the difference, which is based on the numbers of time-series observations used to compute the two statistics ($1/(1/N_S+1/N_L)$). The cross-sectional means are weighted by the same weights. The mean ratio of average block quote size to average block relative spread is computed from only four stocks because the subsample included only four block-eligible stocks. The daily volume statistics are computed only from days on which only one tick was used. The means for these variables include only 22 stocks because four of the subsample stocks did not trade for a full day on a second tick.

	Tick Size			
Variable	Smaller Tick	Larger Tick	Paired *t*-statistic	N
Average Price (FF)	515	559	6.91	26
Average Inside Quote Size (Thousand FF)	162	334	6.73	26
Average Inside Quote Size (Shares)	372	685	5.77	26
Ratio of Average Inside Quote Size to Average Relative Spread (Thousand FF/Percent)	1382	2121	3.68	26
Ratio of Average Block Quote Size to Average Block Relative Spread (Thousand FF/Percent)	2678	2975	0.93	4
Average Relative Spread (Percent Basis Points)	66	58	2.29	26
Average Spread (Ticks)	28	4	-18.25	26
Average Spread (FF Centimes)	331	375	4.32	26
Average Trade Size (Thousand FF)	104	108	1.20	26
Average Trade Size (Shares)	239	236	-0.26	26
Average Daily Number of Trades	48	37	-0.57	22
Average Daily Volume (Million FF)	5	4	-0.26	22
Average Daily Volume (Thousand Shares)	11	8	-0.03	22

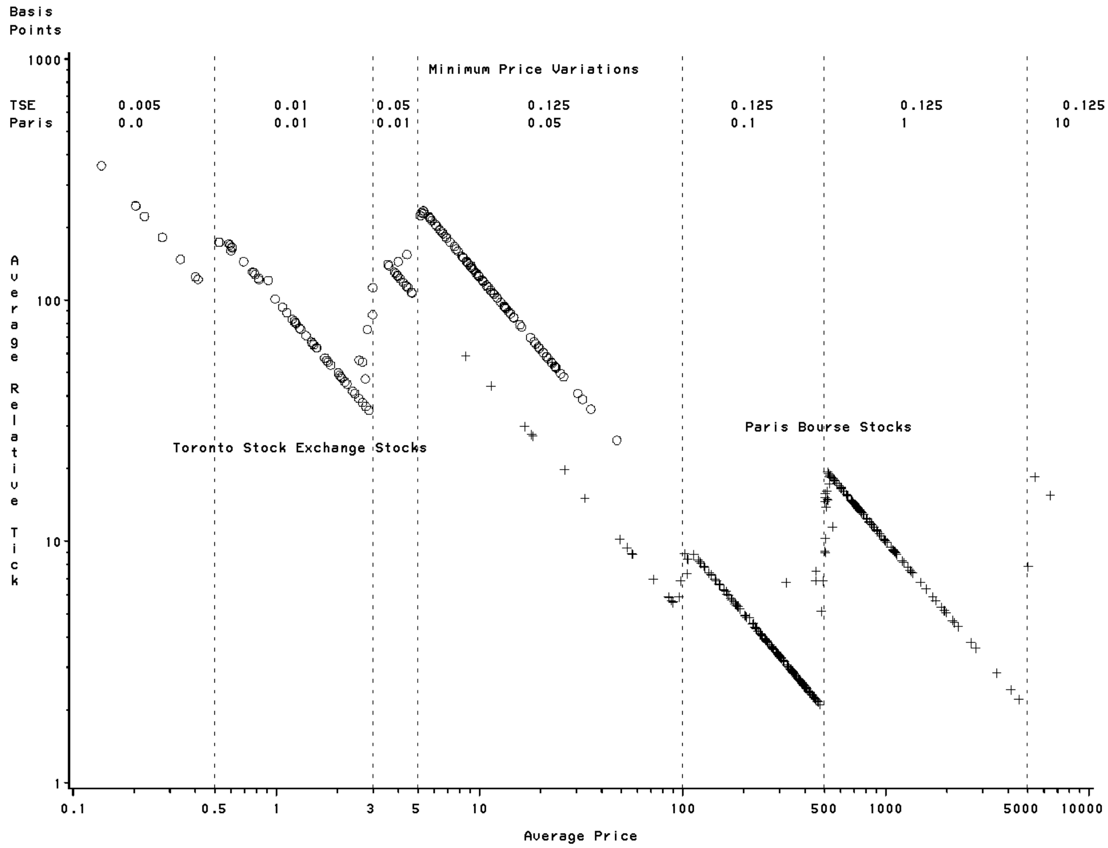

Figure 1. Logarithmic Scatter Plot of Average Relative Tick Size on Average Price. The average relative tick size is the time-series average of the ratio of the exchange minimum price variation to the trade price. It is expressed in basis points. The average price is expressed in local currency units (Canadian dollars for the TSE stocks and French Francs for the Paris Bourse stocks). Most points lie along 45 degree lines because most stocks traded on only one minimum price variation during the sample period. This figure shows that the relative minimum price variation was much greater for the TSE stocks than for the Paris stocks. Only 38 TSE stocks have average relative tick sizes smaller than the maximum found in the Paris sample and only 5 Paris stocks have average relative tick sizes greater than the minimum found in the TSE sample.